JOURNAL OF

THE INSTITUTE OF PETROLEUM

FOUNDED 1913 + INCORPORATED 1914

Vol. 36 SEPTEMBER 1950 No. 321

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Published by the Institute of Petroleum.
Address: Manson House, 26 Portland Place, London, W.1.
Telephone No.: LANgham 2250.
Telegraphic Address: Instpetech, Westdo, London.
Printed in Great Britain by Richard Clay and Company, Ltd., Bungay, Suffolk.

Price 10s. 0d. Annual Sub. £4 14s. 6d. (Post Free)

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Vol. 36. No. 321. September 1950.

THE INSTITUTE OF PETROLEUM.

An Ordinary General Meeting of the Institute of Petroleum was held at Manson House, 26 Portland Place, London, W.1, on May 10, 1950, with Mr T. Dewhurst (Past-President) in the Chair.

The Minutes of the preceding Ordinary General Meeting, held on April 12, 1950, were read, confirmed, and signed.

The General Secretary (D. A. Hough) read the list of elections to membership since the preceding ordinary general meeting.

The Chairman: Both the authors of the paper to be presented this evening are well known to the geological members of the Institute, at least by reputation. As the result of much painstaking research they have designed a successful method of conducting experiments on the movement of oil through sands. The paper gives a very full account of their researches and also the results of one or two experiments they have carried out by means of their method.

Further research and experiment on the lines they have devised should throw new light on the movement of fluids through sands, and may well prove valuable in connexion with several important aspects of oilfield development.

The following paper was then read by S. E. Coomber.

THE APPLICATION OF RADIOACTIVE TRACER TECHNIQUES TO THE STUDY OF THE MOVEMENT OF OIL IN SANDS.

By S. E. Coomber * (Assoc. Member) and E. N. Tiratsoo * (Member).

Summary.

This paper describes the results of preliminary investigations into the possibility of using radioisotopes in following the movement of oil in sand bodies. The basic theory of radioactive tracer work is outlined, and details are given of the apparatus employed and the technique recommended. Methods of measuring the absorption properties of laboratory materials for the radiation of radioactive iodine are described, and the bearing of the results on quantitative measurement is discussed.

Experiments have been made on the movement of oil through sands of differing grades and its accumulation at a coarse–fine interface in order to define the technique and reliability of such measurements in dynamic conditions. The potentialities of these techniques in reservoir-engineering investigations is outlined.

Introduction.

The development of the atomic energy programme has made available in Britain at a very modest cost a large number of radioactive isotopes. These materials, which can be supplied to any *bona fide* research worker

* Oil Technology Department, Royal School of Mines.

by the Atomic Energy Research Establishment (A.E.R.E.) at Harwell, have opened up a wide vista of potential applications.

The use of radioactive isotopes in research results from the facts that by their use it is possible to distinguish substances which are chemically identical, and very small quantities of an element (down to orders of less than 10^{-12} g) can be detected and measured.

The only account published to date of the use of these materials in petroleum reservoir-engineering investigations, of which the authors are aware, is by Russell, Morgan, and Muskat.[5]

The incorporation of a small proportion of radioactive material in a fluid renders the movement of that fluid easily detectable from outside the vessel or pipe in which it is contained. This principle has already been applied in American pipeline practice in following the movement of scrapers pumped along the lines by the incorporation of a small element of radioactive cobalt in each unit; it has also been applied to mark the interface of different liquids flowing along a pipeline, by adding a radioactive isotope of barium in the form of a soap at the initial pump station.

The research which is being carried out by the present authors has as its primary object the investigation of fluid distribution in sand, oil, and water mixtures. While the average content of oil and water in a sand can be determined by simple means, details of the distribution of both fluids cannot be so obtained because of their mobility and the resulting change in distribution as soon as sampling is attempted. A method of assessing the oil and water content without disturbing the system in any way is therefore necessary, and this requires the detection of one fluid by a device external to the system. The use of radioactive tracers seemed ideally suited to the purpose.

During the course of the work, problems relating to choice of isotope, methods of measurement, sources of error, and laboratory technique have arisen, and it is felt that a survey of these matters would serve as an introduction to the application of radioisotope-tracer technique to oil-production problems and possibly be of some assistance to workers contemplating entering the field, which appears likely to be of increasing importance to the geologist and petroleum engineer.

Choice of Isotopes.

In this work the intention has been to trace the movement of oil and water through a porous medium. It has therefore been necessary to "tag" one or other of these fluids. The element chosen had clearly to be relatively highly soluble in one fluid compared with its solubility in the other. Another consideration was the fact that radiation had to be detected after it had passed from the interior of the sand body through the wall of any container in which the sand was held, and therefore γ-rays were necessary, since the absorption of β-radiation would have been excessive. Finally, the half-life of the element chosen had to be a matter of a few days. If a longer period had been accepted, it would have meant that while a considerable range of experiments could have been done with one batch of radioisotope, in the event of the contamination of the laboratory a correspondingly longer period would have had to elapse before operations

could be resumed. The problem of waste disposal is also more difficult with a long-life element. On the other hand, if an element of too short a life is used, then the period available for each experiment is unduly restricted, and corrections have continually to be made for the decrease in activity of the material being used.

The decision whether to work with the isotope in oil-soluble or water-soluble form was not easy to reach, because if special compounds had to be made, the difficulty of organic synthesis on a micro-scale and with a highly dangerous substance was very great. On the other hand, the work was to be done on sands in which water was the continuous medium and oil discontinuous. There seemed to be a much better chance of success, therefore, if the oil were followed rather than if an attempt were made to interpret fluctuations in count from the water.

After a consideration of all these factors it was decided that the oil must be sought in preference to the water and that one of the halogens would be the most suitable " tagging " element to use. There are various halogen derivatives of hydrocarbons which are liquids with not too high a vapour pressure at room temperature, and which are soluble in hydrocarbon oil, although only sparingly soluble in water. It was felt that if part of the halogen content of one of these compounds could be made radioactive the substance would fulfil all requirements. It was suggested by Dr Seligman of A.E.R.E., Harwell, that the desired compound should be put in the pile with the object of converting part of the halogen to its radioactive isotope. Ethylene dibromide had already been irradiated successfully, and since it has a low solubility in water (0·431 g per 100 ml) and Br^{82} is a γ-emitter with a half-life of 34 hr it was first decided to use that compound.

In practice, considerable difficulties were experienced in the use of the irradiated ethylene dibromide. It seemed that during bombardment in the Harwell pile, some molecular breakdown took place, and although there was also recombination, a certain amount of free bromine was left in the liquid. Free radioactive bromine is a dangerous substance because of the ease with which it is vaporized and inhaled. Careful washing of the ethylene dibromide was therefore necessary, but even after this had been done an exceptionally large amount of Br^{82} in some form was transferred to any water with which it came into contact. In fact, it was found that after shaking the washed ethylene dibromide with distilled water and separating, the aqueous extract had 20 per cent of the activity of the oily layer. This was obviously responsible to a considerable extent for the difficulty experienced in detecting changes in oil concentration in a water-wet sand. Therefore, further work with irradiated ethylene dibromide was discontinued.

Attention was then given to radioactive iodine (I^{131}). It is a γ-emitter and has a half-life of 8 days, and these properties, together with the fact that it can now be obtained in separated form, make it very suitable for tracer work with hydrocarbon oils. There is no need of complicated syntheses of organic compounds, because elemental iodine is considerably more soluble in hydrocarbon oil than in water. Working with oil containing I^{131}, a distribution coefficient for iodine between oil and water of $2{\cdot}5 \times 10^3$ was obtained.

The element iodine has a stable isotope I^{127} and five radioactive isotopes—

I^{124}, I^{126}, I^{128}, I^{130}, and I^{131}. Of these, only I^{130} and I^{131} have been produced in quantity and are the isotopes most frequently used for tracer work with the element. As I^{130} has a half-life of only 12·6 hr its use is very limited.

The radioactive isotopes of iodine are produced by the bombardment of tellurium by deuterons in the cyclotron.

The I^{131} is produced in solution as carrier-free iodide. The iodine can be liberated quite easily by oxidation with acid peroxide and then solvent-extracted with a hydrocarbon oil. The oil used in this research was a fraction boiling between 175° and 200° C and distilled from a commercial kerosine. An equal volume of a gas oil which has been filtered through fuller's earth was added to the iodine in kerosine solution. The addition of the gas oil gave a product of suitable viscosity for the experiments on flow of oil through sands. Furthermore, it was found that it also improved the distribution coefficient for iodine between oil and water, and the figure of $2{\cdot}5 \times 10^3$ already quoted was obtained with this mixture.

Counting Apparatus.

The type of radiation counter used in these experiments was the Geiger–Müller (G.M.) tube. This is a simple and convenient instrument readily available in a variety of forms suitable for particular purposes.

It consists essentially of a cylindrical metal cathode and a fine anode wire, generally of tungsten, mounted in a glass tube containing a gas–vapour mixture, usually consisting of argon at 9 cm pressure and alcohol vapour at 1 cm pressure. Such a basic type of tube can generally only be employed to detect γ-radiation, since the glass wall may be too thick to permit β-radiation to penetrate to the sensitive volume.

It has been found that if a potential difference of about 1000 V is held between the anode and cathode of a G.M. tube it becomes sensitive to incoming radiation and can be used with a suitable form of amplifier and registering system to record the intensity of the radiation falling upon it.

The counter tubes used in this research are of two types. For the routine measurements of the absorption coefficients and the flow of the "tagged" fluids a 20th Century Electronics Ltd. type G10 γ-counter was used. It had a cathode of lead gauze, which gives approximately five times the efficiency of copper or carbon for low-energy γ-radiation such as that emitted from I^{131}. The overall length of this tube is 19·5 cm, its outside diameter is 2·5 cm, and the effective cathode length is 8·5 cm. The optimum operating voltage was 1190, and the plateau length * some 200 V. The average background count when shielded was about 35 counts/min. This tube is supplied with a standard British four-pin base.

For liquid counting in experiments in which the distribution of radioactive iodine between water and oil samples was measured, the liquid counter tube (type M. 6) was used. This was a standard Pyrex glass tube (MRC-2) with a threshold voltage of 890 and a plateau of 250 V. The

* In a well-constructed G.M. counter, variation of voltage supply will have a negligible effect on the recorded counting rate between the threshold voltage and a higher voltage at which the counting rate will begin to increase rapidly. The flat portion of the voltage-counting-rate curve is termed the "plateau."

cathode consisted of a finely divided layer of graphite on a borosilicate base, and the anode was a fine tungsten wire. This G.M. tube was 14 cm long, and the active length of the cathode was 13·2 cm. The external diameter of the tube was 1·5 cm. It was surrounded by a glass skirt, 16·2 cm long, joined to the base, with an annular clearance of 1·75 mm. The annular volume was 15 ml, and the glass skirt had a slightly lipped edge to facilitate pouring of liquids or powdered solids. The metallic anode and cathode connexions of the G.M. tube protruded below the skirt.

The counting apparatus used for laboratory measurement was a standard piece of apparatus, incorporating a counting circuit with external extinguishing discriminators and pulse-shaping and limiting stages. These feed either a valve-operated, rate-of-count meter or a multivibrator pulse lengthener operating a mechanical recorder capable of counting accurately up to 600 per minute.

With the integrator, the slowest rate of counting is dependent upon the duration of the pulses, the time constants of the circuits, and the meter itself, and is of the order of 100 per minute. There is thus a good overlap between the two methods of counting.

The integrator is less accurate than the mechanical counter. If accurate high-speed counting is required, scaling circuits would have to be introduced. For the purpose for which this instrument was used in the present research, these were not necessary.

The H.T. unit supplying the G.M. tube provides an adjustable output up to 1300 V by the use of metal rectifiers. The circuit has been described by Graves.[1]

Absorption Coefficients.

The determination of the approximate absorption coefficients of various materials for incident γ-rays is important from the point of view of laboratory experiments, as well as the more obvious health hazards. In the initial stages of this work it was necessary to determine the absorption coefficients of various materials for the γ-rays emitted by radioactive iodine. Since the walls of the cells employed in the various experiments were made of brass or Perspex, the absorption coefficients of these materials had to be determined to ascertain their effect in absorbing the radiation. Subsequently, experiments were made with cells full of oil and of sand to determine the absorption coefficients of these materials.

γ-rays may be considered as quanta of energy or photons whose reactions with matter result in their loss of energy and gradual absorption. These effects fall into three main groups :—

(a) *The Compton Effect.*

The γ photon behaves as a corpuscle with mass and momentum, and on collision with an electron projects it according to the laws of momentum.

(b) *Photoelectric Effect.*

The incident γ quantum may give up its energy to an electron of an atom with which it collides, detaching it completely from the outer electron rings.

(c) *Ion-pair Formation.*

The electromagnetic field of the incident γ-ray may be sufficiently strong to eject electrons from the absorber atom.

In general, a beam of γ-radiation is absorbed exponentially in passage through matter.

A general exponential equation can be written to express as a first approximation the absorption of mono-energetic γ-rays of a single wavelength in a given medium. It is :—

$$I/I_0 = e^{-\mu x}$$

where I_0 is the original intensity of radiation, and I is the intensity after passage through a thickness x of the medium.

μ is a characteristic property of the medium called the coefficient of absorption. It sums the absorption due to the factors of Compton recoil, photoelectric absorption, and pair formation.

Since the absorption due both to the Compton effect and the photoelectric effect decreases as the energy of the incident γ-ray beam increases, while the absorption due to ion-pair production increases, it follows that for some intermediate energy the total absorption coefficient for any element will show a minimum value.

In the experimental determination of the absorption coefficients of the various materials described below, the photoelectric and pair-formation processes were negligible compared with the Compton process, since the maximum energy of the γ-rays from the I^{131} was only 0·367 million electron volts (m.e.v.).* Since I^{131} is not mono-energetic in its γ spectrum, having also a 0·080 m.e.v. component, in any absolute determination of absorption coefficients, this radiation would have to be filtered out.

In these experimental determinations of the absorption coefficients needed, a source of radiation was chosen which approximated as nearly as possible to a point source. One-tenth of a ml of oil containing radioactive iodine in solution was placed in a small glass tube which was suspended by a wire cradle from a retort stand. The G.M. tube was placed in its lead cylinder in a horizontal position at a distance from the source, which was large enough compared with the diameter of the G.M. tube to make the pencil of rays impinging on the tube approximately parallel.

Readings were taken first of the background with the counter in the lead shield and no radioactive material present, then with the radioactive capsule at a measured distance (usually 30 cm) from the end of the lead cylinder, and subsequently with various thicknesses of the material being investigated interposed between the G.M. tube and the source.

In the case of sand samples, the sand was contained in cells of various thicknesses made of thin brass, which could be interposed in turn between the source of radiation and the G.M. tube.

By these arrangements, which admittedly can only be considered as approximate, a rapid and direct method of assessing the absorption coefficients required for the work in hand was obtained.

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* The m.e.v. is a unit of energy equal to $4{\cdot}5 \times 10^{-20}$ kilowatt-hours.

The results obtained were plotted in the form of a family of exponential curves as shown in Fig. 1.

The absorption coefficients of the various materials were calculated from these curves as follows :—

The coefficient of absorption, μ, of any material may be expressed as the reciprocal of the thickness that will reduce the intensity of an incident

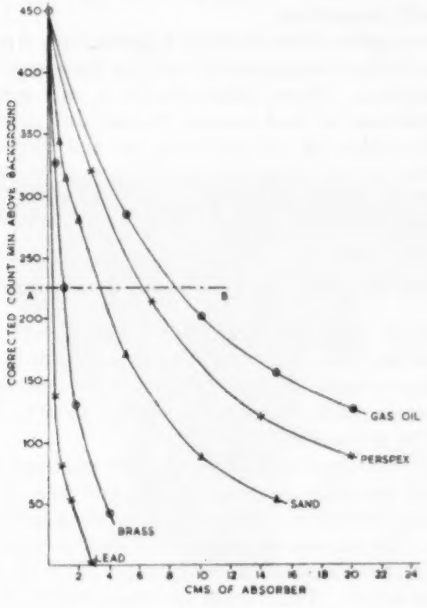


FIG. 1.

FAMILY OF CURVES OBTAINED IN ABSORPTION EXPERIMENTS FOR VARIOUS MATERIALS.

beam of γ-rays to $1/e$ of its original value. To deduce the intensity, the thickness $x_{\frac{1}{2}}$, called the half-value thickness, is required.

Then, since

$$I/I_0 = e^{-\mu x}$$
$$\log_e I_0/I = \log_e 2 = 0{\cdot}693 = \mu x_{\frac{1}{2}}.$$
$$\therefore \mu = 0{\cdot}693/x_{\frac{1}{2}}.$$

The line AB on Fig. 2 gives the values of $x_{\frac{1}{2}}$, which when substituted in the above formula allow the values of μ to be calculated. The results obtained are summarized below :—

	Lead.	Brass.	Sand.	Perspex.	Gas oil.
$x_{\frac{1}{2}}$ cm . . .	0·3	0·9	3·4	6·0	8·4
μ . . .	2·3	0·77	0·24	0·12	0·08

It was also possible to use this experimental set-up to investigate the practical factors involved in arranging the beam of the incident γ-rays in the optimum way for the purposes of the tracer experiments.

The problem here was to arrange the end section of the lead container in which the G.M. tube was contained so that it would absorb as nearly as possible all the incident γ-rays from I^{131}, while allowing to pass a thin pencil of rays down its central hole. This hole had to be of sufficient diameter to give sensitive results when oils of only slightly differing activity were set against it, while at the same time not being so narrow as to cut down the proportion of rays penetrating to the G.M. tube to an unreasonably small proportion.

In order to investigate these factors, experiments were made in which first of all the absorption coefficient of lead for the γ-rays of I^{131} was found as previously described. From these results it was possible to calculate the minimum thickness of lead needed to cut out nearly all the γ-rays falling on it. The effect of the diameter of the central hole was then investigated by placing the radiation source up against varying thicknesses of interposed lead and measuring the amount of radiation that penetrated four successive diameters of hole.

Measurement of Oil Content of Sands.

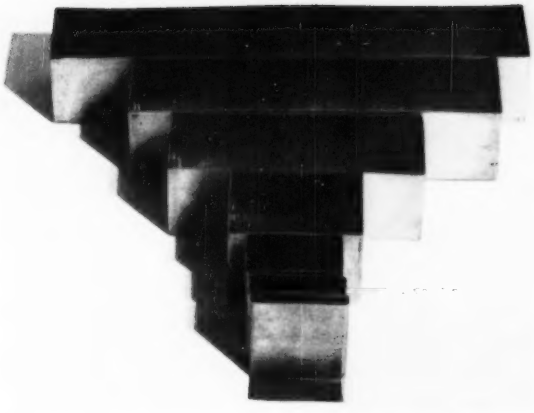
Although in tracer work the emphasis is on detection of the presence and position of an invisible substance, the value of the technique is greatly enhanced if measurements of quantity are also possible. Experiments therefore were made with various sand–oil mixtures to determine the extent to which this is possible.

Three brass cells of depths 0·5, 1·0, and 2·0 cm respectively were filled with a mixture of kerosine containing I^{131} and gas oil, and the counts from each cell were recorded. The cells were then emptied, cleaned, and filled with sand. The oil was then dropped slowly on to the sand so that it filled the pore spaces, and when completely filled the counts from each cell were again recorded. The results are presented in Fig. 2.

It will be seen that the counts from oil alone are not proportional to the depth of oil; the ratio (counts to depth of oil) decreases with increased depth. This effect is due to self-absorption in the oil, and must be taken into account if working with varying thicknesses of material.

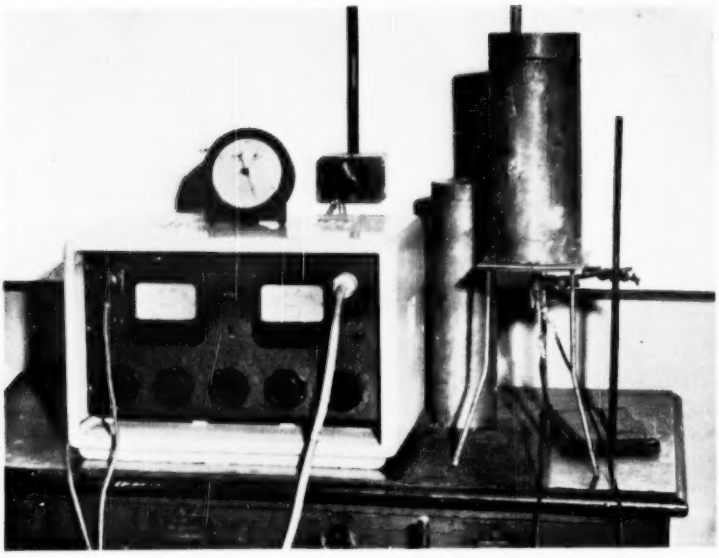
The phenomenon of absorption becomes even more pronounced when sand as well as active oil is present in the cell. The factor of most interest, however, is the ratio between counts for oil and sand and the counts for oil alone, in a cell of a given thickness. If a true measurement of oil content of the sand, and, incidentally, the porosity of the sand, is to be obtained, in all cases the ratio should be constant. In point of fact, it is not, and in the particular example given the magnitude of the ratio begins to decrease appreciably when the thickness exceeds 1·2 cm. Beyond this, absorption due to the sand as compared to self-absorption in the oil begins to be increasingly important.

Any attempt to derive a mathematical expression for these relationships is fraught with considerable difficulty. Not only must one take into account factors such as the difference in distance between the G.M. tube and the front and the back of the active body, the different coefficients of absorption of the oil, the sand, and also of the cell wall if it is sufficiently thick, and the fact that the radiation is complex, but it must also be remem-

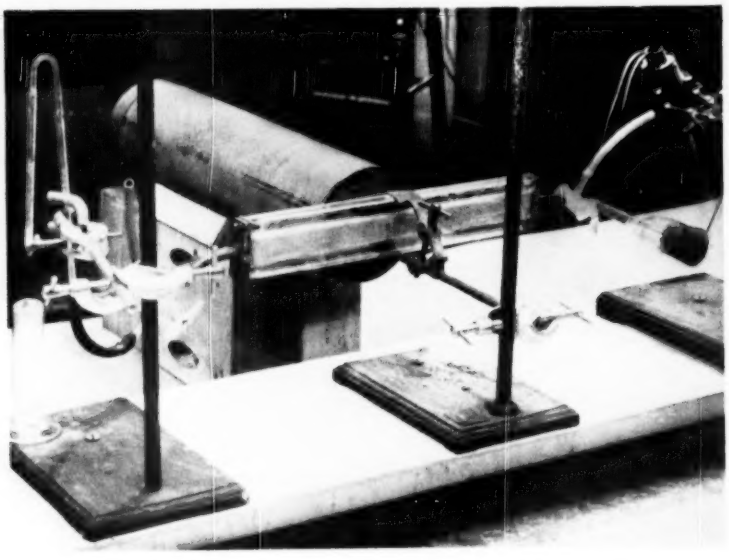


THE THIN BRASS CELLS USED IN THE EXPERIMENTS.

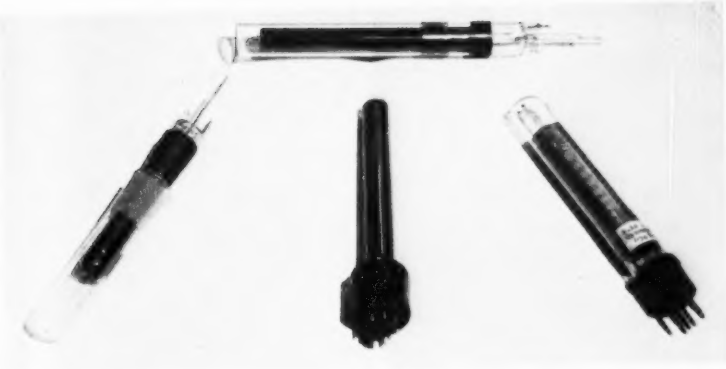
[*To face p. 550.*



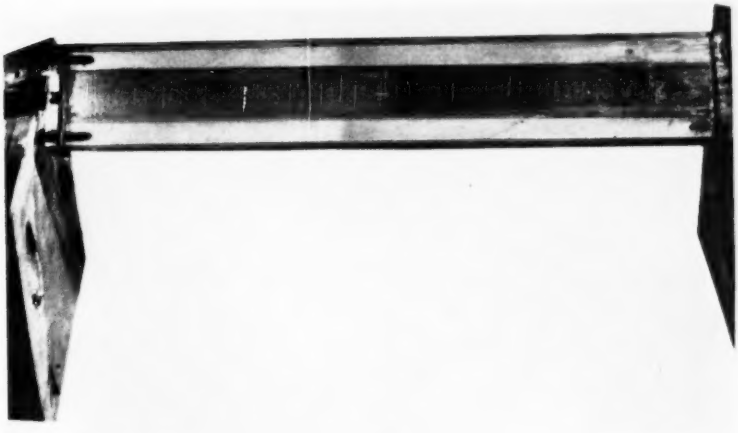
THE COUNTING EQUIPMENT (LEFT) SHOWING INTEGRATOR DIAL AND MECHANICAL COUNTER. TWO LEAD CYLINDERS ARE SHOWN ON THE RIGHT, IN ONE OF WHICH A G.M. TUBE IS IN POSITION.



CLOSE-UP OF THE LABORATORY SET-UP FOR THE STUDY OF OIL MOVEMENT IN SAND ILLUSTRATED IN FIG. 1.



VARIOUS TYPES OF G.M. TUBES USED IN THE WORK. THE G.10 TUBE ON THE RIGHT IS THE SPECIALLY SENSITIVE GAMMA-COUNTING TUBE.



CLOSE-UP VIEW OF THE PERSPEX CELL SHOWING THE FOUR SAND DIVISIONS

bered that the radiation itself may set up secondary effects which may also affect the count. It is therefore better to make practical measurements with the materials to be used and to evaluate the effects directly.

The range of thickness of a sand body from which a true value of oil content or porosity can be obtained will obviously depend on the energy level of the radiation which is being used. This varies greatly for different isotopes. The use of isotopes with high-level γ-ray energies, however, demands an increased thickness of lead shield if collimation is to be effective.

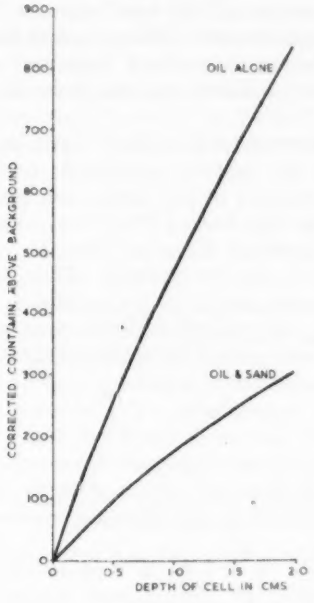


FIG. 2.

CURVES SHOWING EFFECT OF INCREASING CELL DEPTH.

For instance, with Br^{82} 3 in of lead were necessary, whereas with I^{131} a little more than 1 in sufficed.

From the foregoing, it will be seen that the simple measurement of oil content of a sand is, within limits, possible. It must be noted at this point, however, that the limitations appear to be even greater than already defined. It was discovered that sand, when wetted with oil containing I^{131} and subsequently drained and washed carefully a number of times with inert carbon tetrachloride, still retained sufficient radioactive material to give a count well above background. The same phenomenon was noted, though to a lesser degree, with sand which was water-wet before oil was passed through its pores. This is clearly a matter of importance in detailed studies of oil distribution in rocks, and it is being further investigated. Adsorption of various isotopes on to the walls of glassware and other containers has already been noted by various workers—*e.g.*, the adsorption of P^{32} on to laboratory glassware.[4]

Measurement of Oil Flow in Sands under Dynamic Conditions.

This work was undertaken first for the purpose of studying the distribution of oil in water-wet sands. That is, it was concerned with purely static conditions in the sand, and it has been shown how, by taking into account various factors, such as the absorption of γ-rays by different substances, the coefficient of distribution of the isotope between oil and water, the absorption of the isotope by the surface of the mineral grains, etc., the average oil content of the sand opposite the collimation hole in the lead shield can be determined. While, at first glance, it would therefore appear that the required tool has been fashioned, even though not completely perfected, some consideration will show that the matter must be taken a stage farther.

The amount and distribution of oil in a water-wet sand depends on the method of filling and the history subsequent to filling, as well as upon the individual characteristics of the water, oil, and sand. In order that the measurement of the distribution of oil in a water-wet sand should have some meaning, it is necessary therefore that the process of accumulation of the oil in the sand should be studied. Thus, the second stage in the research was the measurement of oil concentration in dynamic conditions.

When oil is moving, various difficulties at once arise. The obvious ones are that the G.M. counter cannot be in more than one place at a time, and the count must be made over a definite period of time, during which the oil may have moved appreciably. For reasons such as these, it was decided to repeat work the basis for which was already well established and study the conditions and technique necessary to demonstrate results which have been already demonstrated in other ways. Illing's experiments on migration and accumulation at interfaces seemed ideally suited to this purpose.[2, 3]

A rectangular tube, 1 in $\times$ $\frac{1}{2}$ in in cross-section and 12 in in length, was constructed of Perspex. Transparent material was chosen for this purpose so that the filling could be watched. This tube was partly filled with water into which sand was dropped so that tight packing was achieved and air eliminated from the pore space. The sand had clean, fairly well-rounded grains, was well washed with water, and divided into two grade sizes : a coarse grade which passed through a No. 18 B.S. screen and was retained on a No. 25; and a fine passing No. 36 and held on No. 52.

A 3-in bed of coarse sand was deposited in the tube. This was followed by 3 in of fine sand, and the process repeated. When filled, the tube was set up as shown in Fig. 3, and free water flow was established.

Fifteen ml of kerosine containing approximately 2·5 millicuries of I^{131} was diluted with another 10 ml of kerosine, and the whole was made up to 50 ml with filtered gas oil. This oil mixture was then placed in the appropriate vessel on the apparatus, and the oil, in the form of small droplets, injected into the water-stream entering the sand.

The G.M. tube, being necessarily contained in a heavy lead shield, was cumbersome and difficult to move. Therefore, the sand tube and its associated apparatus was instead traversed in front of the shield. Since

detailed quantitative data were not being sought, elaborate traversing gear was not provided, and the sand tube assembly was mounted on a simple carriage which, by careful levelling, enabled readings to be taken in a central line along the tube.

At the commencement of the experiment, a high rate of flow was maintained, about 200 ml of water per hour with an oil content of approximately 6 per cent. At a later stage, the water flow was reduced to about 20 ml per hour. Control of oil injection was a little more difficult at this low rate of flow; the oil content of the water-stream averaged about 10 per cent.

A principal object of these experiments was to detect changes in the tube while the oil was moving. A long count was, therefore, impossible, and it was felt that if short counts would suffice to demonstrate the behaviour of the oil the method could be deemed practical. Statistical accuracy with such a short counting time is poor unless the counting rate

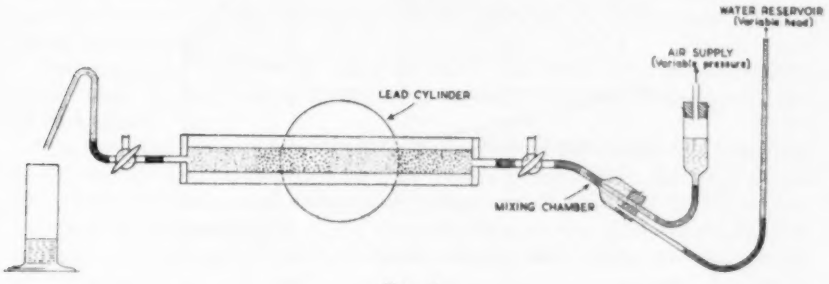


FIG. 3.

ARRANGEMENT USED TO STUDY THE FLOW OF OIL AND WATER THROUGH SANDS OF DIFFERENT GRADES.

The lead cylinder—shown to scale—contains the G.M. tube.

be high. This can be achieved by a high degree of activity in the oil, by a large-diameter collimating hole, or by a combination of both. Increasing the size of the hole in the shield decreases the sensitivity of detection of changes in oil concentration, yet it was not desirable to work at higher than 5-mc levels. A 0·4-mm hole was finally selected, and it was calculated from data already at hand, that with this collimation a sand 100 per cent saturated with the activated oil would give a count of about 900 per minute (including background).

As the flow of oil and water through the sand proceeded, the apparatus was traversed to and fro in front of the lead shield, and counts were made. The results are presented in the set of diagrams in Fig. 4, in which the counts per minute from various parts of the tube are plotted against the counting position at various times. It must be realized that the time, say 5.15 p.m., on the diagram is to some extent a misrepresentation, in that the first count recorded on that particular plot might have been at 5.10 and the last at 5.20. This, however, is unavoidable if one does not use a number of G.M. tubes and very elaborate simultaneous recording equipment. It is interesting to note, however, that in spite of this limitation

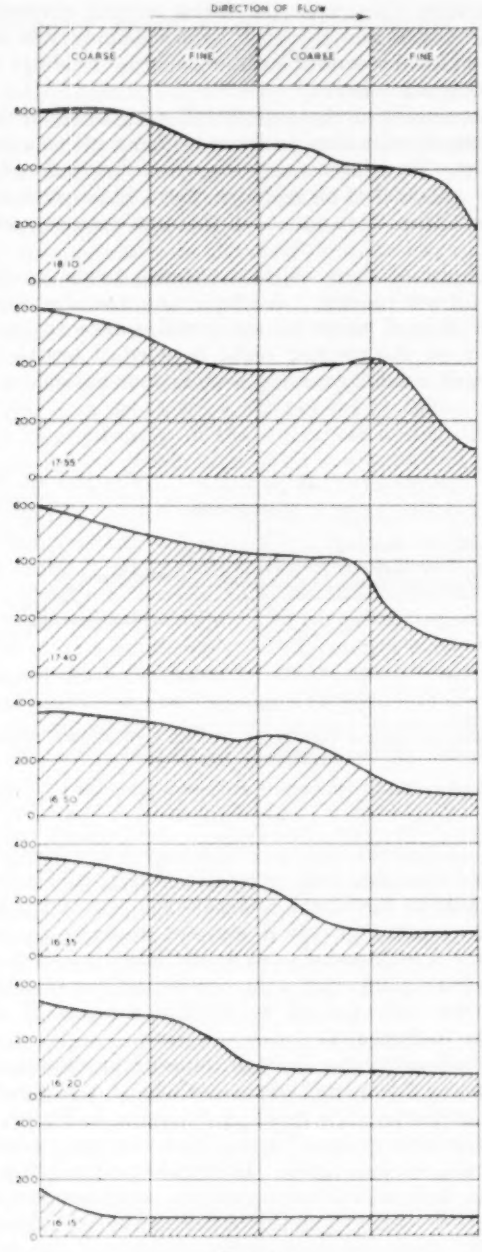


FIG. 4.

THIS SERIES OF CURVES ILLUSTRATES THE BUILD-UP OF OIL IN THE ALTERNATING COARSE- AND FINE-SAND LAYERS OVER A PERIOD OF APPROXIMATELY 2 HR.

The vertical axis shows the corrected count per minute recorded, and the horizontal axis shows the distance along the tube.

the process of movement and accumulation of oil in the sand body can be clearly followed.

At the beginning, the oil concentration quickly built up in the first coarse sand section to a value of about 50 per cent of the pore space. Furthermore, at the rate at which the fluid was passing through the tube, the first coarse–fine interface was penetrated with no noticeable hesitation, and so the build-up progressed through the first coarse-sand section and the first fine-sand section into the second coarse sand. At this stage, because it was desired to demonstrate accumulation at the coarse–fine interface, the rate of flow was reduced to 20 ml/hr.

With the lower rate of flow, the build-up of oil concentration behind the second coarse–fine interface can be plainly seen in the diagram. Complete break-through and accumulation in the last fine-sand section did not take place until this concentration was more or less uniform in the second coarse sand, and was of the order of 45 per cent of the pore space. After break-through had occurred, the build-up in the last fine-sand section went steadily forward; at the same time more and more oil accumulated in the preceding sections.

The purpose of this work being to check the method of measurement rather than the measurements themselves, comment is restricted to details of technique.

The fact that the build-up in oil concentration at the coarse–fine interface was demonstrated so clearly indicates that a 4-mm hole in the lead shield will give reasonably good collimation. This would probably be too coarse for detailed measurements of oil concentration in fine-grained sands, but in that case the work should be done in static conditions, and the length of count could be adjusted to suit its magnitude. It is very fortunate that the larger-size hole suffices for dynamic conditions, because with it one-minute counts are not too inexact. Better results would probably have been obtained if the I^{131} concentration in the oil had been four times as strong (20 mc per 100 ml oil), but special laboratory arrangements would have been needed if such concentrations had been used.

The throughput of water in the sand, especially in the early stages, was relatively high, but readings in the sections distant from the point of entry and before the oil front had reached them show that the inference made from the distribution coefficient, that the count would refer almost entirely to the oil, is justified. However, there are signs that before full break-through was achieved some oil had passed the interface. This could be due either to a patch of bad packing in the fine sand at the interface or to small globules of oil becoming detached from the throats of larger pores in the coarse sand and so being able to pass without deformation into the fine sand. It is a matter of interest to find out if this latter suggestion is possible, and further investigations are being made to that end. The quantities behaving thus are small, and are unlikely to be detected without the aid of a sensitive apparatus such as the G.M. counter. Another matter which is receiving attention is the fact that penetration of the second coarse–fine interface took place when the oil concentration on the coarse side was appreciably less than had been expected.

Before work with the sand tube was completed it was held with its long axis vertical and, with the first coarse-sand section downwards, was

allowed to drain by gravity for three days. At the end of this time measurements were made along the tube, and these are plotted in Fig. 5. Interpretation of these results is not simple, although at first glance it appears to be merely a matter of higher retention in the fine sand. The adsorption of the iodine (or iodine-bearing complex) on to the surface of the mineral grains, already discussed in an earlier paragraph, must be taken into account, and this would be expected to give higher counts in the fine sand because of the increased surface area. It may be assumed, therefore, that, until the matter has been investigated at different levels of radio-

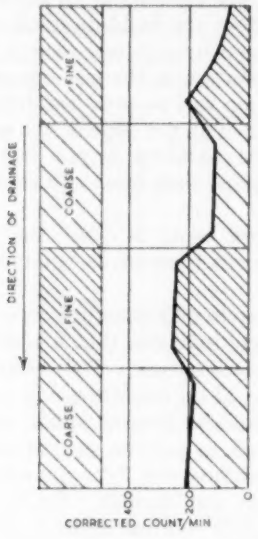


FIG. 5.
EFFECT OF GRAVITY DRAINAGE OF OIL FROM THE SAND LAYERS.

activity with various substances, the significance of measurements made on rock from which radioactive oil has been wholly or partially removed will remain in doubt.

FUTURE RESEARCH.

The work outlined is essentially of a preliminary nature, and was designed to evaluate the various factors concerned and to explore the practicability of the technique. These limited aims have been largely achieved. It has been shown that quantitative measurements of oil in a sand can be made and its course traced. The precision of the method could be improved, however, and this is largely due to factors, such as absorption of the isotope on to the mineral surfaces, which were not fully investigated in the earlier work. The programme of future work which is already in progress, therefore, will be developed along three main lines :—

1. The improvement of instrumental technique.
2. The detailed investigation of absorption of the isotopes on to various minerals and associated factors.

3. The application of the technique to the evaluation of the properties of rocks containing various fluids and to the study of the problems of fluid flow in those rocks.

The obvious improvements needed in instrumental technique are provision for multiple and automatic recording and for improved sensitivity. The design of recording gear should not be difficult and would follow well-known principles, but it is likely to be relatively costly and therefore beyond the means of a University department. For these reasons this line is not being followed.

Improved sensitivity is concerned with good collimation and the accuracy with which very low counts may be made. Collimation, provided the absorption coefficients of the various materials are known correctly, is a matter of geometry, but the better the collimation the smaller the amount of radiation reaching the G.M. tube from the isotope. If this is cut down to the same order as the cosmic-ray count, excessive counting times are necessary unless the latter is eliminated. With very lengthy times of count a substantial background variation may occur, so it would be necessary to have a second complete counting apparatus making a simultaneous count.

Another method of eliminating the cosmic background which is being investigated, utilizes a scintillation counter in place of the standard G.M. apparatus. This device, which is still in course of development, is relatively insensitive to cosmic radiation.

The amount of absorption of isotopes by minerals is obviously related to the absorption of oil, or, more probably, certain constituents of the oil on to the surface of the mineral grains. Such phenomena are, of course, well known, but the use of radioactive isotopes provides a much more delicate test for their investigation than has been possible in the past. Thus, apart from the determination of the error in quantitative measurement of oil content, the work can be expected to throw light on the preferential absorption of various constituents of oils by minerals. Also, the radioactivity of certain shales is probably related to the high degree of absorption of certain heavy radioactive elements by the clay. This is supported by some preliminary investigation made by the authors on the adsorption of uranium salts on clays.

Little need be added on the work relating to the distribution and movement of oil in sands, for its applications are obvious. Previously, there has been no means of making detailed measurements, and deductions have had to be based on average quantities and such phenomena as were visible on the outside of the sand body. Now some precision seems possible.

The preliminary work on oil flow has been made with oil–water–sand mixtures in which oil movement and quantities have been measured. The systematic investigation of such mixtures is far from complete, but is being pursued. However, these conditions represent only the simplest state in a reservoir rock, and there remains to be considered the far more complex system when, in addition, gas is present. While continuing the measurements on the 2-fluid mixtures, therefore, it is hoped to start some exploratory work on developing a technique for handling three fluids. One approach to this problem may be the use of isotopes emitting different

types of radiation, each fluid being characterized by its own special radiation.

The measurement of the permeability of cores is also under investigation. While the experiments already described have revealed an alternative method of measuring the permeability of a homogeneous core, the problem of measuring the continuously varying permeability of a non-homogeneous core is much more complicated, but it is believed that it may be possible to solve this problem by the use of tracer technique.

In the field, several larger-scale applications suggest themselves. By the use of radioactive tracers, it may prove possible to detect interconnexion between wells. With this in view, it is certainly worth investigating the feasibility of employing a number of long-life isotopes for this purpose. The movement of mud fluid into the walls of a hole is another promising field of study, as are also many problems relating to water flooding and ultimate oil recovery.

This outline of future research is a fitting conclusion to a paper on a new research tool. The possibilities of this method of investigation are very many.

Acknowledgments.

The authors wish to acknowledge the receipt of a Government grant for scientific investigations through the Royal Society.

They also wish to thank Professor V. C. Illing, F.R.S., for his advice and encouragement.

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Discussion.

The Chairman: I am sure you will all agree that the authors have carried out, and carried out successfully, a very difficult and laborious piece of research, and have evolved a promising technique for conducting experiments on the movement of fluids through sands.

Professor V. C. Illing: In a sense I think I was partly responsible for these researches in suggesting to Mr Coomber some years ago that, if we could arrive at a method of estimating the percentage of oil in a sand at any one spot, it would round off the researches which Dr G. D. Hobson and I had already done, the results of which were presented to the Institute. We felt that we had not been able, in tracing the concentration of oil at the interfaces, to make definite quantitative estimates, and we hoped that this technique would help. I believe that the results already indicate possibilities in this direction. I would not say more.

At one time we considered adopting a colorimetric method for this

estimation, but the method which is being adopted by the authors has an advantage over a colorimetric method in that it has a wider application. I hope the authors will pursue their work, for it has considerable practical application. The common association of water and oil in one and the same sand is too well known to need discussion, but we do need to study the separate existence and behaviour of the oil and the water. I do hope that Mr Coomber and Dr Tiratsoo will be able to continue along this line of research and eventually make the method quantitative. I do not underestimate the difficulties, but the work they have done has shown that they are approaching it in a sound scientific spirit, and the later stages may well provide the results we all desire.

Dr J. Birns: The experimental technique described would appear to apply itself directly to a homogeneous formation only, in that, since the absorption of the gamma-radiation is exponential in form, the major contribution to the measured gamma intensity comes from the oil (containing the I^{131} isotope) nearest the counter. In the case of a non-homogeneous formation, any channelling near to the counter would give higher readings than channelling distant from the counter, although the mean oil concentration across the core at that point may be the same. If there is any doubt about the homogeneity of the core, the implication is that one should take a count at a number of positions around the core.

It would seem that the scintillation method of measuring gamma intensity might be 15 or 20 times more sensitive than the G.M. tube method, and would increase the quantitative precision of the measurements.

Instead of using a gamma-active isotope dissolved in the oil phase, as a method of measuring oil concentration, it might be possible to follow the X-ray-absorption technique used by Muskat *et al* (A.I.M.E. TP.2124. Jan. 1947), where they incorporated 30 per cent iodobenzene in the oil phase to act as a primary absorber for X-rays. In our case a gamma absorber, having a high absorption coefficient compared to oil and water (iodoform or lead tetraethyl?), could be dissolved in the oil phase. A collimated beam of gamma-rays from a $cobalt^{60}$ source could be directed through the core and the transmitted gamma intensity correlated with oil saturation in the core.

Another method may be to replace the gamma source by a neutron source (radium–berylium) and have a neutron beam incident on the core, measuring the secondary gamma intensity as a function of oil concentration in the core.

The application of radioactive tracer techniques in the field have already been applied by the Americans in the measurement of core contamination during core drilling. For following the movement of materials underground or in pipelines the method would appear to have great possibilities. In the laboratory the measurement of capillary heights of fluids in porous media, the surface area of pores, and problems of interdiffusion are further possible examples of the application of isotopes.

Dr E. N. Tiratsoo, replying to the discussion, said: We have been asked about future research, about what we are hoping to do. It will be evident that most of the work that has been done is already of fairly long

standing. We have since made some progress in several directions. This we are not yet prepared to put on a quantitative basis, but it is certainly qualitative.

With regard to possible limitations of the technique and advances that might be made, it is evidently true that this technique has no magic about it, inasmuch as we can only attempt to measure the radiation from the oil that is geometrically available to our counter. That is really the fundamental difficulty, because the G.M. tube is an instrument which may be several inches long and is sensitive along its whole body. Hence, any method of application of the G.M. tube to the sand body involves the difficulty that we have in some way to shield out the radiation coming in from all angles. That means that a large quantity of lead is involved, and the technique becomes very clumsy.

Taking measurements all round a sample is quite right if you are attempting to evaluate the oil content quantitatively. We have tried to do it qualitatively, but we have not yet carried the process through to its logical conclusion. We hope, however, to do it in three dimensions, following the "tagged" fluid through a three-dimensional sand body.

With regard to the other possible techniques, the one which has progressed furthest is with the scintillation counter; the G.M. counter is already somewhat out of fashion, and the counting technique of the immediate future will certainly be scintillation counting, which recapitulates the work of Rutherford in discovering radioactivity and now puts it on a modern basis. A crystal sensitive to the radiation to be measured, is used, and gives off light photons which can be electronically recorded by the use of a photo-multiplier tube. The sensitive area is not larger than the crystal, and the crystal may be a fraction of an inch in diameter. Thus the radiation coming in from all round the crystal can be shielded out without much trouble, without the encumbrance of the G.M. tube and its heavy shielding. We have now reached a stage where at any moment we hope to have our scintillation counter actually working; thereby, we can improve very greatly—20 times and perhaps even more—the sensitivity of our counting, cutting down the background and time of count, and have a quantitative method of getting into and around all sorts of samples which at the moment the G.M. tube cannot approach.

With regard to the suggestion to use a neutron source, I think the investigation of these methods will show that they are rather too cumbersome and in some cases too dangerous for the average laboratory. In particular, neutrons are not pleasant things to have around. But with the gamma-ray technique and using a scintillation counter I think we shall be able to put this new technique on a quantitative basis and do a lot of the things which Professor Illing hopes we shall do.

Vote of Thanks.

The Chairman: I am sure you will all wish me on your behalf to thank the authors for having prepared this very novel and interesting paper.

(The vote of thanks was heartily accorded.)

SO_2 AND SO_3 IN EXHAUST GASES OF INTERNAL-COMBUSTION ENGINES.

By M. J. VAN DER ZIJDEN, J. E. VAN HINTE, and J. C. VAN DEN ENDE.*

SUMMARY.

Starting from the assumption that knowledge of the SO_3-content of exhaust gases would assist the study of the influence of SO_3 on wear and fouling of internal-combustion engines, the SO_3-content of exhaust gases of some spark-ignition and diesel engines was determined.

The quantity of SO_3 present was found to be very low in all cases, by far the greater part of the sulphur being present as SO_2. The correct determination of SO_2 in addition to SO_3 in the exhaust gas is, however, very difficult, because SO_2 is rapidly oxidized during sampling and analysing due to compounds of the peroxide type present in the exhaust gas and to water.

Oxidation will also occur on cold cylinder walls, and the SO_3 thus formed is considered as a main source of wear and fouling of engines.

There is obviously no relation between the true SO_3-content of the exhaust gas and the SO_3 found on the cylinder walls, and SO_3-determinations of the exhaust gas are therefore of little use for the wear and fouling problem of engines.

INTRODUCTION.

IN recent years considerable attention has been given to the relation between sulphur content of engine fuels and wear of such engine parts as piston-rings and cylinders.

In addition to corrosion by sulphur in the fuel, a study has been made of the adverse effect of sulphur oxide-containing gases on the fouling of the internal-combustion engine. A review of work has recently been given by Broeze and Wilson.[1]

The research work concerning the effect of sulphur in fuel included not only engine problems, but also the influence of sulphur oxides formed as a result of the combustion of solid or liquid fuel in boilers on the corrosion of, for instance, economizers. In this connexion mention should be made of the work done by Johnstone *et al* [2] in the U.S.A. and by the Boiler Availability Committee [3] and the British Coal Utilization Research Association (B.C.U.R.A.) in Great Britain.

In 1938, Broeze and Gravesteyn [4] drew attention to the fact that there is some correlation between the wear of cylinders and piston-rings in diesel engines and the sulphur content of the fuels.

They reported that most of the sulphur present in a fuel will burn to SO_3, leading to sulphuric acid attack of cylinders and piston-rings.

Their results were confirmed by Cloud and Blackwood [5] and the U.S. Bureau of Mines,[6] who reported that the percentage of S present in the form of SO_3 in the exhaust gases of an engine may be as high as 60 to 90 per cent of the total sulphur, and is dependent on the load and speed of the engine.

The work of Broeze and Gravesteyn has been continued with engines of different types in order to investigate whether all types of engines produced

* Koninklijke/Shell Laboratorium, Amsterdam and Delft, Holland.

the same high percentage of SO_3 in exhaust gases, or whether the SO_2/SO_3 relation was influenced by engine design or operating conditions. In this new work the methods of analysis were different from those used in the previous investigation.

Description of Experiments.

Method Using Glass Filters for Absorption of SO_3.

According to Lohfert,[7] SO_3 mists can be caught by passing gases containing such mists through glass filters. As it is probable that SO_3 in

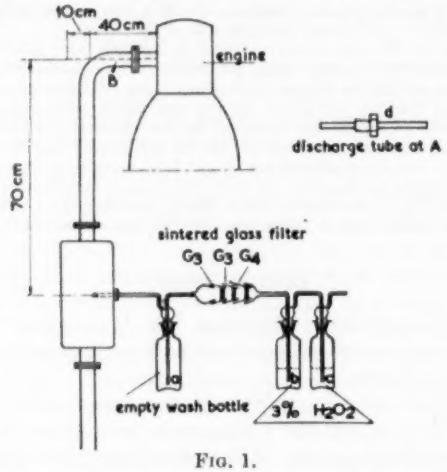

Fig. 1.

EXHAUST GAS ABSORPTION BY FILTER METHOD IN DIESEL ENGINE.

cooled exhaust gases will be present as a sulphuric acid mist, the exhaust gases were passed through a pyrex capillary, a series of glass filters, and two bottles filled with hydrogen-peroxide solution (see Fig. 1).

Table I.

SO_3 and SO_2 Determinations in the Exhaust Gas of a Caterpillar Diesel Engine Using Glass Filters for Absorbing SO_3.

Exp. no.	B.M.E.P., kg/cm.²	S in fuel, %.	R.p.m.	Litres of gas analysed, n.t.p.	Exhaust gas analysis, %.			Total sulphur in exhaust gas (calculated), mg S/m³.	SO_3 and SO_2 found.				Total SO_3 + SO_2 found, mg/m³.	S found/calc. balance, %.
									S as SO_3.		S as SO_2.			
					CO_2.	O_2.	CO.		mg/m³.	% of total.	mg/m³.	% of total.		
1	5·2	0·96	850	16·8	8·0	9·9	0	485	29	5·5	494	94·5	523	107·9
2	5·2	0·96	850	16·9	7·5	10·1	0	450	52	9·0	530	91	582	119·7
3	5·2	0·96	850	24·9	6·7	11·3	0	400	16	4·5	422	95·5	438	110·9
4	5·2	0·96	850	32·1	8·1	10·0	0	505	15	2·8	511	97·2	526	104
5	5·2	0·96	850	16·0	8·2	9·5	0	496	19	4·1	438	96	457	92·5
6	0·264	0·96	850	69·6	2·0	18·0	0	120	9	6·0	142	94	151	125
7	2·64	0·96	850	34·0	4·5	14·4	0	272	16	4·8	324	95·2	340	125
8	2·64	0·96	850	42·0	4·5	14·4	0	422	4	1·3	319	98·7	323	119
9	0·264	0·96	850	34·4	1·9	17·7	0	115	2	1·65	140	98·4	142	123
10	3·7	0·96	850	33·0	5·8	13·0	0	352	13	3·18	412	97	425	120

Table II.

SO_2 and SO_3 Determinations in Exhaust Gas of C.F.R. High-speed Gasoline Engine Using Glass Filters for Absorption of SO_3.

Exp. no.	S in fuel, %.	Mixture strength.	R.p.m.	B.M.E.P., kg/cm².	Litres of gas analysed n.t.p.	Exhaust gas analysis, %.			Total sulphur exhaust gas (calc), mg S/m³.	SO_3 and SO_2 found.				Total round $SO_3 + SO_2$.	S found calc balance %.
										S as SO_3.		S as SO_2.			
						CO_2.	O_2.	CO.		Mg/m³.	% at total.	Mg/m³.	% of total.		
1	2·4	0·92	840	1·48	10·0	13·2	2·7	0·1	2000	58	2·9	1950	97·2	2008	100
2	2·4	0·97	840	1·48	8·3	13·8	1·6	0·3	2000	54	2·0	2240	98	2295	115
3	2·4	1·30	840	2·94	15·1	8·8	0·5	8·7	2540	18	0·5	1940	99[5]	1958	77
4	2·4	0·90	840	2·94	7·8	12·0	3·5	0·5	1810	129	6·5	1791	93[5]	1920	106
5	2·4	1·12	840	4·4	17·6	12·2	0·4	3·7	2365	33	1·0	2725	99	2758	116
6	2·4	1·15	840	4·4	17·6	11·9	0·2	4·2	2400	30	1·0	2500	99	2530	105
7										31 *		2560 *		2591	108
8	2·4	1·08	840	4·4	17·8	13·3	0·4	2·2	2340	43	2·0	2120	98	2163	92
										40 *		2185 *		2225	
9 †	0·20	1·05	840	4·4	42·3	13·3	0·8	2·0	188	27	12·6	185	87·4	212	112[5]
10	1·0	1·07	840	4·4	33·5	13·6	0·4	1·5	940	27	2·5	995	97[5]	982	105
11	1·0	1·07	840	4·4	33·5	13·6	0·6	1·6	936	31	3	906	97	937	100
12	1·0	1·0	840	1·48	34·2	13·9	1·0	0·5	890	23	2·5	957	95[5]	880	99[5]
13	1·0	0·75	840	2·94	34·2	10·4	6·0	0·2	660	60	8·5	655	91[5]	715	108
15	1·0	0·93	840	2·94	33·9	13·0	1·9	1·1	860	68	7	888	93	956	111
						12·6	2·3	1·3							
						13·3	2·2	0·5		65 *		926 *		991	115
						13·3	2·1	0·5							
						13·2	2·4	0·3							
16		0·93	840	2·94	33·9	12·9	2·9	0·3	847	50	5	927	95	977	115
						13·3	2·4	0·3							
						13·6	1·7	0·5		43 *		846 *		889	105
19 ‡	2·0	1·35	1800	2·94	16·9	8·6	0·1	9·7	2280	nil	nil	947		947	41·5
												1060 *			
20 ‡	2·0	1·35	1800	2·94	16·8	8·4	0·2	10·1	2310	nil	nil	1015		1015	44
												1125 *			
21	2·0	0·73	845	2·94	17·1	10·2	6·8	0·2	1310	50	4·5	1045	95·5	1095	84
22	2·0	0·76	845	2·94	17·1	10·4	6·2	0·2	1345	58	5	1120	95	1178	87[5]
										49 *	4	1165 *	96	1214	90
23	2·0	0·80	1800	2·94	17·2	11·2	5·2	0·2	1420	134	10·5	1130	89·5	1164	88
										108 *	9·4	1060 *	90·6	1168	80
24	2·0	0·80	1800	2·94	17·7	11·3	4·9	0·2	1445	186	12·4	1290	87·6	1476	102
										190	14	1163 *		1353	93·6
25	2·0	0·68	1800	1·48	17·6	9·3	7·8	0·2	1180	52	5	990	95	1042	88
										47 *	4·3	1050 *		1097	
26	2·0	0·68	1800	1·48	17·5	9·6	7·4	0·3	1235	54	5	1000	95	1054	85·5
										47 *	4·2	1070 *		1114	90·5
27	2·0	0·80	1800	2·94	17·4	11·4	4·7	nil	1410	165	11	1310	89	1475	105
										154 *	11·4	1195 *		1349	96
28	2·0	0·80	1800	2·94	17·5	11·2	5·1	0·2	1380	176	11·5	1300	83·5	1476	107
										157 *	11·6	1195		1352	

* Gravimetric determinations. † In experiment 9 the engine was running irregularly.
‡ In these experiments, carried out at a very rich mixture strength, the exhaust gases contained H_2S.

Condensation of sulphuric acid in the capillary tube was prevented by insulating it. An empty bottle between capillary and filters was used to receive any condensate formed before the glass filters.

After a measured volume of exhaust gas had been passed through the apparatus, the sulphuric acid caught in the empty wash bottle and in the filters was determined volumetrically or gravimetrically, and from this figure the quantity of SO_3 was calculated.

The sulphuric acid in the hydrogen peroxide bottles was determined in the same way. From this figure the quantity of SO_2 was calculated.

Tests with a Caterpillar diesel engine using this method were carried out at different loads, and the results are summarized in Table I.

This same method was used for the analysis of exhaust gases of a C.F.R. gasoline engine running at different mixture strengths.

The mixture strength in all experiments was derived from the composition of the exhaust gas by means of the Ostwald diagram.

The results are presented in Table II.

The data presented in Tables I and II show that, with the method described above, very low values for SO_3 are found in the exhaust gases of the diesel and gasoline engines mentioned.

For comparison the methods described by the U.S. Bureau of Mines [6] and by Cloud and Blackwood [5] for the analysis of the exhaust gases of the same Caterpillar diesel engine were used. The results are presented in Table III.

TABLE III.

SO_2 and SO_3 Analysis by the U.S.B.M. Method and by the Cloud and Blackwood Method.

Method.	B.M.E.P. kg/cm².	S in fuel, %.	R.p.m.	Litres of gas n.t.p.	Exhaust gas analysis, %.			Total sulphur in exhaust gas (calc). mg S/m³.	SO_2 and SO_3 found.				Total $SO_2 + SO_3$ found, mg S/m³.	S found calc. balance, %.
					CO_2.	O_2.	CO.		S as SO_2.		S as SO_3.			
									mg/m³.	% of total.	mg/m³.	% of total.		
U.S.B.M.	5·2	0·96	850	36·5	8·0	9·7	0	485	495	93	38	7	533	110
,,	5·2	0·96	850	36·0	8·2	9·2	0	500	526	97·5	15	2·5	541	108
C.B.	0·26	2·75	850	27·3	2·1	17·4	0	350	342	100	nil	0	342	98
,,	2·64	2·75	850	17·7	4·5	14·4	0	757	622	80	155	20	777	102
,,	5·2	2·75	850	15·5	7·5	9·7	0	1250	1045	82·5	222	17·5	1267	101
,,	5·2	2·75	850	26·6	8·0	9·6	0	1335	970	68	460	32	1430	107

It is evident that values for SO_3 obtained by the "glass-filter method" differ widely from those obtained when using the U.S.B.M. or the Cloud and Blackwood method.

In none of the methods are sulphur oxides lost during analysis. The difference in results between these methods can therefore be explained only when :—

(1) significant amounts of SO_3 pass the glass filters in the glass-filter method, as a result of which part of the SO_3 is determined as SO_2; or

(2) significant amounts of SO_2 are oxidized in the U.S.B.M. and Cloud and Blackwood methods as a result of which part of the SO_2 is determined as SO_3.

In order to ascertain which explanation is the most feasible, further experiments were carried out.

First, mixtures of SO_2 and SO_3 of known compositions were analysed according to the " filter method."

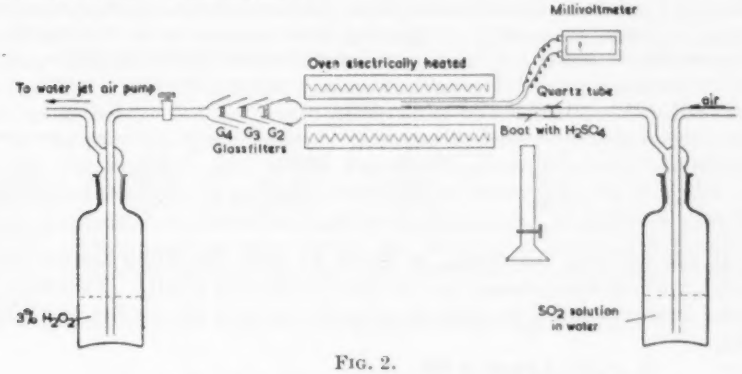

FIG. 2.

LABORATORY APPARATUS FOR SEPARATION OF SO_3 AND SO_2.

The SO_2 was obtained by passing air through an aqueous solution of SO_2 ($\frac{1}{2}$ per cent concentration). The quantity used was found by determining SO_2 in the solution before and after the experiment by oxidation with H_2O_2 and titration of sulphuric acid.

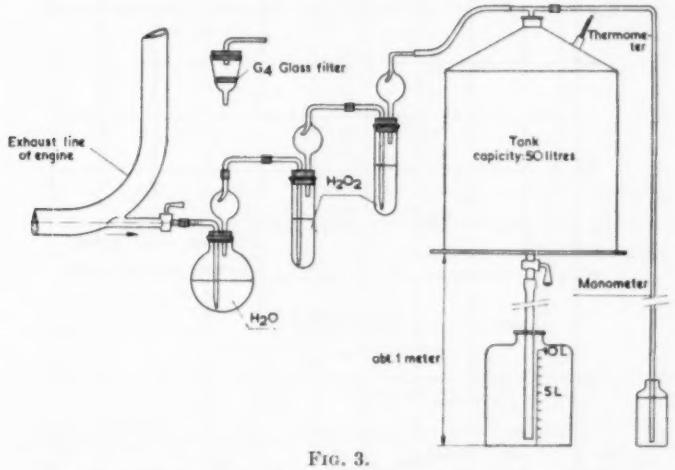

FIG. 3.

APPARATUS FOR DETERMINATION OF SO_3 AND SO_2 IN ENGINE EXHAUST GAS.

H_2SO_4 mist was produced by heating a known quantity of H_2SO_4 in a quartz tube.

The mixture of air, SO_2, and H_2SO_4 mist was passed through an oven electrically heated to 450° C. The gas mixture then passed a series of glass filters and a bottle filled with H_2O_2 solution.

Fig. 2 is a sketch of the apparatus, and the results obtained are given in Table IV.

TABLE IV.

Analysis of Synthetic Mixtures of SO_3 and SO_3 by the Filter Method.

Quantity added expressed as ml 0·1N-NaOH.		Quantity found expressed as ml 0·1N-NaOH and as percentage of quantity added.			
SO_3.	H_2SO_4.	SO_3.		H_2SO_4.	
11·65	Nil	11·65	100%	Nil	—
9·10	2·77	8·85	97·5%	2·70	97·5%
9·55	1·54	9·50	99·5%	1·55	100·5%

It follows from the results in Table IV that the filters absorb all the sulphuric acid mist present in a mixture of SO_2 and H_2SO_4. Therefore, the filter method applied to exhaust gases should give the correct quantity of SO_3.

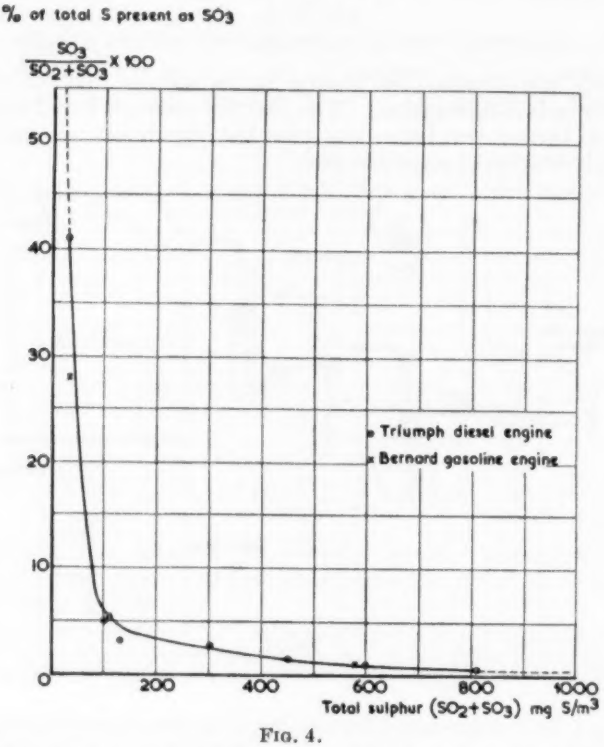

FIG. 4.

SO_3/SO_3 ESTIMATION IN EXHAUST GASES OF A DIESEL AND A GASOLINE ENGINE.

However, there is still a possibility that SO_3 in exhaust gases is not present as a sulphuric acid mist but as sulphuric acid vapour or as SO_3 gas. According to Dooley and Goodeve [8,9] this is less probable, but it may be

expected that sulphuric acid vapour or SO_3, if present, will be absorbed in a bottle containing water.

The following analysis method was therefore applied.

A measured quantity of exhaust gas was passed through three absorption bottles (Fig. 3), the first containing water, the other two hydrogen peroxide solution.

After sampling engine exhaust gas, a nitrogen current was passed through the absorption train, and at the same time the contents of the first bottle were boiled for 20 minutes in order to transfer the SO_2 dissolved in the water-bottle quantitatively into the hydrogen peroxide solutions. Finally, the sulphuric acid in the water and peroxide bottles was determined volumetrically or gravimetrically, from which data the SO_3 and the SO_2 concentration in the exhaust gas were calculated. With this apparatus SO_2/SO_3 determinations were carried out in exhaust gases of a Triumph one-cyl, four-stroke diesel engine and a Bernard one-cyl, four-stroke gasoline engine.

The results of these analyses are presented in Tables V and VI.

TABLE V.

(Triumph diesel engine.)

Test no.	S-content of fuel, %.	Engine load, B.M.E.P., kg/cm².	$CO_2 + CO$ in exhaust gas, %.	S/m³ in exhaust gas, mg.				S as SO_3, %.
				Total found.	Total calc.	As SO_3.	As SO_2.	
1	<0·05	5·0	0·7	29	—	12	17	42
2	0·31	3·5	4·7	100	92	9	91	9·9
3	0·45	4·5	5·8	130	160	8	122	6·5
4	0·63	2·2	3·1	110	120	11	99	11·1
5	—	4·5	5·8	250	230	12	238	5·0
6	2·2	2·2	3·1	450	430	12	438	2·7
7	—	3·5	4·5	600	620	11	589	1·9
8	—	4·4	5·5	810	770	8	802	1·0

TABLE VI.

(Bernhard gasoline engine.)

Test no.	S-content of fuel, %.	Mixture strength.	$CO_2 + CO$ in exhaust gas, %.	S/m³ in exhaust gas, mg.				S as SO_3, %.
				Total found.	Total calc.	As SO_3.	As SO_2.	
1	0·62	1·0	15·0	580	585	5	575	0·9
2	<0·05	1·0	—	25	—	7	18	28
3	0·62	1·0	14·6	595	570	5	590	0·8

Sampling velocity for test 1 : 15 l/hr.
" " " 3 : 120 "

It appears that the estimated total quantity of sulphur correlates fairly well with the amount calculated from the carbon analysis of the exhaust gas and the sulphur/carbon/hydrogen ratio of the fuel. The discrepancies are probably due to the inaccuracy of the determination of CO_2 and CO, which was carried out with the Orsat apparatus. Moreover, small percentages of unburnt or partially burnt hydrocarbons were neglected. The fact that sometimes more and sometimes less sulphur was found by analysis than was calculated, supports this assumption.

The results are represented graphically in Fig. 4. It appears that a high percentage of SO_3 is found when the total quantity of sulphur in the exhaust gas is small. Such a low sulphur content of the exhaust gas can be obtained by using a low-sulphur fuel or, in the case of diesel engines, by running at low loads. On the other hand, a low percentage of SO_3 is found when the total quantity of sulphur is high. This is the case at high loads when high-sulphur fuel is used.

From Tables V and VI it will be clear that this remarkable result is obtained because the absolute quantity of SO_3 in the exhaust gases is practically constant and independent of sulphur content of fuel or engine load. The absolute quantity of SO_3 is very small.

A series of experiments similar to those recorded in Table V was carried out with the same engine using the apparatus shown in Fig. 3, but with a G4 glass filter between the water-absorption bottle and the hydrogen-peroxide bottles.

With this arrangement it could be expected that SO_3 as gas as well as in the form of a sulphuric acid mist would be caught.

The results of these experiments are given in Table VII.

TABLE VII.

SO_2/SO_3-analysis of Exhaust Gas of Triumph Diesel Engine Using a Water-absorption Tube and Glass Filter for SO_3 Absorption.

S-content of fuel, %.	Engine load, B.M.E.P., kg/cm².	$CO_2 + CO$ in exhaust gas, %.	S/m³ in exhaust gas, mg.				S as SO_3, %.
			Total found.	Total calc.	As SO_3.	As SO_2.	
0·63	2·9	3·1	110	120	32	78	29
0·63	4·5	5·8	230	230	10	220	4·4
2·2	2·7	3·1	390	430	22	368	5·6
2·2	4·6	5·8	720	770	35	685	4·9

The absolute values for SO_3 content, expressed as mg sulphur per m³ exhaust gas, differ only little from those mentioned in Table V.

The efficiency as regards SO_3 absorption of the apparatus used for the experiments recorded in Table VII was checked by analysis of SO_3/air mixtures obtained by evaporation of known quantities of sulphuric acid as described before.

It was found that all SO_3 was absorbed in the water-absorption bottle and the filter, and that no trace of SO_3 could be detected in the hydrogen peroxide solution.

It is clear, therefore, that the low absolute values of SO_3 in exhaust gases recorded in Tables I, II, V, VI, and VII are reliable. No traceable amounts of SO_3 have escaped analysis.

In order to check this point some tests for SO_2 in exhaust gases were carried out using Müller's method.[10] According to Müller a hydrochloric acid–$SnCl_2$ solution reduces SO_2 to H_2S and does not affect the SO_3 content. Nitrous oxides, too, are reduced so rapidly that they do not influence SO_2 or H_2S. H_2S can be absorbed in cadmium acetate solution, and the cadmium sulphide formed is determined iodometrically. Results of these tests are recorded in Table VIII.

TABLE VIII.

SO_2/SO_3 Determinations in Exhaust Gas of Caterpillar Diesel Engine Using the Müller Method.

Experiment no.	B.M.E.P., kg/cm².	S in fuel, %.	R.p.m.	Litres of gas analysed n.t.p.	Exhaust gas analysis, %.			Total sulphur in exhaust gas (calc.), mg S/m³.	SO_3 and SO_2 found.				Total $SO_3 + SO_2$ (found), mg S/m³.	S found/calc. balance, %.
									S as SO_3.		S as SO_2.			
					CO_2.	O_2.	CO.		mg/m³.	% of total.	mg/m³.	+ of total		
1	0·264	2·75	850	17·8	2·0	17·6	0	334	?	?	318	95[a]	318	95[a]
2	2·64	2·75	850	17·65	4·5	14·4	0	753	?	?	730	97	730	97
3	5·2	2·75	850	8·77	7·9	10·1	0	1320	?	?	1290	97[a]	1290	97[a]

It is evident that, when applying the Müller method, which in principle is quite different from the other absorption methods, a very large amount of the S in the exhaust gas of this Caterpillar engine is also found to be in the form of SO_2.

Oxidation of SO_2 after Sampling.

It was stated above that a second explanation for the large differences found for SO_3 content of exhaust gases when different analysis methods are used would be the possibility of oxidation of SO_2 to SO_3 in, or just before, the absorption apparatus in those methods with which high values for SO_3 are found.

It is a well-known fact that SO_2 dissolved in water is fairly easily oxidized to SO_3. Several investigators analysing SO_2/SO_3 mixtures have taken certain precautions to avoid this oxidation. Antioxidants such as glycerine or *iso*propyl alcohol have been used, or the absorption of SO_2 has been effected at low temperatures or, as far as possible, in nitrogen atmosphere.[5, 6, 7, 11, 12]

Several investigators checked the efficiency of their method for SO_2 estimation, and of the various anti-oxidants used, by analysing mixtures of air and SO_2 of known compositions.

It has been found that some of the methods proposed actually give fairly reliable data when analysing synthetic mixtures of SO_2, SO_3, and air.

When a mixture of pure SO_2 and air is added to the exhaust gas of a diesel engine running on sulphur-free fuel ($< 0{\cdot}005$ per cent S) it was established, however, that more SO_3 was found in the SO_2/exhaust gas mixture than in

the SO_2/air mixture. In both cases this SO_3 must have been formed in or just before the absorption apparatus.

The analysis method used in this case was that illustrated in Fig. 3.

TABLE IX.

Analysis of Mixtures of SO_2/Pure Air and SO_2/Sulphur-free Exhaust Gas.

Mixture.	S/m³ estimated gas, mg.			S/m³, total found, mg.	S as SO_3 in mixture, %.
	SO_3 in H_2O bottle.	SO_2 in first H_2O_2 bottle.	SO_2 in second H_2O_2 bottle.		
SO_2/air	0·8	87	Nil	88	0·9
SO_2/sulphur-free exhaust gas	9	170	Nil	179	5

The results in Table IX indicate that even the very low values reported earlier for SO_3 in exhaust gas (see Tables V and VI) may be partly due to oxidation of SO_2 after the exhaust gases have left the engine, either in the exhaust line or in the analysis apparatus.

Exhaust gases apparently contain substances which can oxidize SO_2 at low temperatures much more easily than pure air.

The effect of the presence of these products when using another analysis method was also investigated.

A mixture of SO_2 and pure air added to the exhaust gas of an engine running on sulphur-free fuel ($< 0{\cdot}005$ per cent S) was analysed according to the U.S.B.M. method, and the results are given in Table X.

TABLE X.

Analysis of Mixture of SO_2/Pure Air and SO_2/Sulphur-free Exhaust Gas According to the U.S. Bureau of Mines Method.

Mixture.	S/m³ estimated as:		S/m³, total found, mg.	S as SO_3 in mixture, %.
	SO_3, mg.	SO_2, mg.		
SO_2/air	27	1103	1130	2·4
SO_2/sulphur-free exhaust gas	160	230	390	41
	38	4	42	91

Comparing the results of Tables IX and X, which were obtained with the same engine, it is evident that the large percentages of SO_3 found when using the U.S.B.M. method must have been formed in the analysis apparatus under the influence of strongly oxidizing substances present in the exhaust gas. These substances in aqueous medium have the same effect as hydrogen peroxide. They may be nitrous oxides or peroxides formed from the fuel.

It is possible that the alkaline medium used for SO_3 absorption in the U.S.B.M. method is partly responsible for the rapid oxidation of SO_2 (see Gilham [13]), but the main cause is the unexpected effect of " active oxygen "-containing products in the exhaust gases of engines. Even low temper-

atures and the use of glycerine as an anti-oxidant, as is done in the Cloud and Blackwood method, cannot eliminate the strong oxidizing effect of these products (see Table III).

That this oxidizing effect was much less pronounced in the glass-filter method is probably due to the absence of an aqueous medium through which the SO_2 has to pass. It was indeed found that higher SO_3 values were obtained if the glass filters were wetted with water.

During the experiments with dry filters a few drops of water may condense in the empty wash bottle and on the filters, so that it may well be that even the low values of SO_3 found with this method have been influenced by oxidation of SO_2 due to these " active oxygen "-containing products.

Also the low and constant values for SO_3 obtained with the apparatus in Fig. 3 (water-absorption bottle combined or not combined with glass filter) are to a certain extent caused by oxidation of SO_2 in the analysis apparatus. That, in the experiments reported in Tables V, VI, and VII, this oxidation was not more pronounced is probably due to the fact that absorption of SO_2 took place in neutral or acid medium, that the time used for analysis was very short, and that after the absorption of the sulphur oxides the chance of oxidation of SO_2 was minimized by immediately driving off the SO_2 from the water-absorption bottle by boiling and passing of nitrogen.

It was established that if boiling was omitted or when boiling was carried out for less than 20 minutes, markedly higher values were found for SO_3, caused by oxidation of SO_2.

Regarding the possibilities of oxidation of SO_2 between engine and absorption apparatus, it was found that some oxidation of SO_2 may take place in iron exhaust lines, the iron oxide present probably functioning as a catalyst.[3] It was also found that leaking exhaust valves may lead to erratic results and too high SO_3 figures.

On the strength of the experience gained in all these tests it may be said that in determining SO_2 and SO_3 in exhaust gases of an engine it is not possible to prevent oxidation of SO_2 to SO_3 completely after the gases have left the engine. The best way of determining SO_3 and SO_2 together and separately is absorption of SO_3 in a wash bottle containing water, followed by filtration through a G_4 sintered-glass filter, and absorption of the remaining SO_2 in one or two bottles filled with hydrogen peroxide solution. To make sure that no SO_3 escapes analysis, a sintered-glass filter can be used after the hydrogen peroxide bottles, although normally this precaution is not necessary.

Taking all possible precautions against oxidation of SO_2 in the water and the filters a series of repeat experiments was made with the Bernard petrol, C.F.R. petrol, and Triumph diesel engines. The results presented in Table XI confirm previous work.

It appears that in the case of the Bernard gasoline engine running at theoretically correct mixture strength, there is practically no SO_3 present in the exhaust gas.

The exhaust gases of a C.F.R. engine running with large excess of air contain a very small amount of SO_3. The same holds true for the Triumph diesel engine. There is a possibility that the small quantity of SO_3 in these last two cases is formed during passage of the gases through the iron exhaust lines.

TABLE XI.

Engine.	S content of fuel, %.	Load, B.M.E.P., kg./cm².	$CO_2 + CO$ in exhaust gas (mixture strength), %.	Oxygen in exhaust gas, %.	Gas (n.t.p.), l.	Test duration, min.	S, mg.				S/m³ in exhaust gas, mg.				S as "SO_3", %.
							First flask (H_2O) + glass filter.	Second flask (H_2O_2).	Third flask (H_2O_2).	G_3-G_3-G_4 glass filters.	Total found.	Total calc.	As SO_2.	As SO_2.	
Bernard	0·62	3·9	14·8 (1·0)	0·2	17·1	23	0·04	11·0	nil	nil	645	580	2	643	0·3
C.F.R.	1·8	3·5	8·7 (0·67)	8·2	17·6	19	0·3	16·5	nil	0·04	956	988	19	937	2·0
„	1·8	4·0	9·7 (0·72)	7·0	17·5	22	0·48	21·6	0·13	0·02	1268	1100	28	1240	2·2
Triumph	0·63	4·3	5·9	10·0	17·6	19	0·24	4·23	nil	nil	254	234	14	240	5·5
„	2·2	4·5	5·8	10·0	17·5	19	0·18	14·0	nil	nil	810	805	10	800	1·3

The low SO_3 content found is in line with the SO_2/SO_3 equilibrium at the high temperatures obtained during combustion (see work of Bodenstein and Pohl [14]).

It is probable that the small quantity of SO_3 formed during combustion undergoes no material change when the gases are cooled down, the reason being that there is too little time available for a change in the SO_2/SO_3 ratio owing to the equilibrium conditions connected with this lower temperature.

Conclusions.

From the tests recorded in this paper it follows that SO_3 present in the form of sulphuric acid mist or vapour can be easily detected by simple analysis methods, viz., absorption in water and/or passage through sintered-glass filters.

Determination of the correct amount of SO_2 in exhaust gases of engines is, however, extremely difficult, due to the rapidity with which SO_2 is oxidized in aqueous media by " active oxygen "-containing products present in the exhaust gas. SO_2 is thus converted into SO_3 and determined as such. It is practically impossible to avoid this oxidation completely.

It can be said, therefore, that when analysing exhaust gases of engines the lowest values found for SO_3 will probably be nearest the truth.

The purpose of this investigation was to ascertain, in connexion with the problem of wear and engine fouling, to what extent the presence of SO_3 in the exhaust gases depends on engine design and operating conditions. It was found that the SO_3 content of engine exhaust gases was extremely low in all the cases examined. This correlates with what could be expected on theoretical grounds. However, SO_2 oxidizes very rapidly under the influence of " active oxygen "-containing compounds in the exhaust gas if the temperature is low enough and an aqueous medium is present. These conditions may exist on the cylinder walls, and would explain the presence of sulphuric acid which has actually been found in engines.

The quantity of SO_3 present in the exhaust gas of an engine, therefore, does not necessarily bear any relation to the wear nor to the formation of insoluble products from the lubricating oil due to the action of SO_3 formed on the cylinder walls.

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THE MEASUREMENT OF THE THERMAL CONDUCTIVITIES OF SOILS, AND THE CALCULATION OF OIL TEMPERATURES IN BURIED PIPELINES.

By K. G. Brummage.*

Summary.

Several large-diameter pipelines are being laid in the Middle East, and others are planned. Some of these will be buried. The temperature of the oil in such pipes is important in the following connexions :—

(1) Through its effect on viscosity, it controls the throughput.

(2) It is sometimes possible to cool the engines at pumping stations by heat exchange with the oil being pumped, and the size of heat exchanger depends on the oil temperature.

(3) The protective coating on the pipe must be chosen to withstand the pipe temperature without deformation.

The oil temperature is determined by the thermal conductivity and the temperature of the soil. In this paper measurements upon existing buried pipelines are described to determine these quantities under summer conditions at various places in the Middle East.

The theoretical analysis is given, including allowances for the insulating effect of pipe-coatings. A simple procedure of general application is then described for calculating the temperature of liquid in turbulent flow in a buried pipeline, and finally the temperature distribution in a representative hypothetical line is determined as an illustration of the method.

List of Symbols Employed.

A	$\dfrac{2\pi K}{\left\{\log_e\left(\dfrac{2h}{r_n}\right) + K\sum_{x=1}^{x=n}\dfrac{1}{K_x}\log_e\left(\dfrac{r_x}{r_{x-1}}\right)\right\}}$.
A'	$\dfrac{A}{2\pi r_1}$, the pipe–soil heat transfer coefficient per unit area of pipe surface.
B	ρcG.
c	Specific heat of the liquid.
E	The maximum percentage error in the measured value of K due to errors in temperature measurements.
G	Volumetric rate of flow of liquid.
H	Rate of heat evolution by friction per unit length of pipe.
h	Depth of centre of the pipe.
J	Mechanical equivalent of heat.
K	Thermal conductivity of soil.
$K_x (1<x<n)$	Thermal conductivity of the xth cylindrical shell around the liquid (K_1 is that of the pipe material).
k_x	Units factor in the expression for X.
k_y	Units factor in the expression for Y.
L	Length of pipe under consideration.
l	Any length of pipe.
N	Hydraulic pressure gradient.
n	An integral number.
P	Hydraulic pressure at any point in the liquid.
Q	Rate of heat flow from unit length of pipe.
Q'	Rate of heat flow from unit area of pipe surface.

* Anglo-Iranian Oil Co. Ltd., Research Station, Sunbury-on-Thames.

r_0	Internal radius of the pipe.
$r_x (1<x<n)$	Radius of the outer surface of the xth cylindrical shell around the liquid (r_1 is the outer radius of the pipe).
T	Temperature of the liquid at the end of a length L.
T_0	Temperature of the liquid at the beginning of a length L.
T_h	Temperature of the soil at a depth h.
$T_x (1<x<n)$	Temperature at the outer surface of the xth cylindrical shell around the liquid (T_1 is the temperature of the outer surface of the pipe).
T_∞	$\left(T_h + \frac{H}{A}\right)$, the temperature to which the liquid trends as it travels along the pipe.
t	Time.
X	$k_x \cdot \frac{2\pi KL}{\rho cG\left\{\log_e\left(\frac{2h}{r_n}\right) + K\sum_{x=1}^{x=n}\frac{1}{K_x}\log_e\left(\frac{r_x}{r_{x-1}}\right)\right\}}$.
Y	$k_y \cdot \frac{GN}{2\pi K}\left\{\log_e\left(\frac{2h}{r_n}\right) + K\sum_{x=1}^{x=n}\frac{1}{K_x}\log_e\left(\frac{r_x}{r_{x-1}}\right)\right\}$.
ρ	Specific gravity of the liquid (assumed to equal the density in g/ml).

Introduction.

The increasing development of the Middle East oilfields and the proposed construction of large pipeline systems to handle their output has emphasized the importance of oil temperatures in such pipes. In both buried and surface lines the oil temperature controls the throughput by its influence on the viscosity, so that maximum throughput is obtained at high temperatures. On the other hand, if the oil is too warm, troublesome pockets of gas may be formed.

Surface lines are subjected directly to the complete daily and annual temperature cycles and, especially in hot climates, allowance must be made for the thermal expansion of the pipes. The method adopted has normally been to build the line slightly zig-zag, as in the Persian field, but with larger pipe diameters this is not practicable. The surfaced sections of the 30-inch pipeline now under construction in Saudi Arabia have therefore been built straight, with substantial anchors at intervals so that the thermal stress is held, instead of being relieved by bending. Additional stresses occur when surface pipes are exposed to the sun, owing to temperature differences between exposed and shaded parts of the pipe, and they introduce the possibility of over-stressing a line which, owing to the steel supply situation, is thin-walled and without corrosion allowance.

Thermal stresses may be avoided by burying the pipe, so that it is lagged by the soil and protected from the extremes of temperature at the surface. Thus, at a depth of 1 to 2 feet the effect of the daily temperature cycle is negligibly small, and the amplitude of the annual cycle is very substantially reduced. The oil temperature in buried pipes is determined by the thermal conductivity of the soil, and by the temperature of the soil at the depth of the pipe. Its magnitude is important not only for the reasons given above, but also because with buried lines in desert localities, where water must be conserved, the pumping engines are sometimes cooled by a closed water system, the waste heat from which is imparted by heat exchangers to the oil being pumped. The success of such a system depends upon the oil temperature, and there must be adequate heat dissipation to the soil between pumping stations. Also, the pipes are normally coated with

bituminous protective layers, and these must be selected to withstand the pipe temperature without deformation or flow.

The calculation of the temperature in a buried pipe containing oil in turbulent flow has been dealt with by Beale, Hartley, Van Dyck, and Van Wyk,[1] and to make satisfactory temperature estimates using this theory it is necessary to know accurately the thermal conductivity and the temperature of the soil. To provide data for future Middle East pipeline developments, measurements were therefore made upon buried pipes in Iraq and Saudi Arabia during the period July to October 1948.

The first part of the present paper is concerned with a theoretical analysis which formed the basis of experimental work in the field, and the second with the development of a simple calculation procedure applicable to any line containing liquid in turbulent flow. Finally, an example is given of the temperature distribution in a representative pipeline, as determined using this method.

PART I.

Theoretical Analysis.

The theoretical treatment is substantially that given by Beale *et al.*[1] It applies only to pipes carrying liquid in turbulent flow, so that there is no

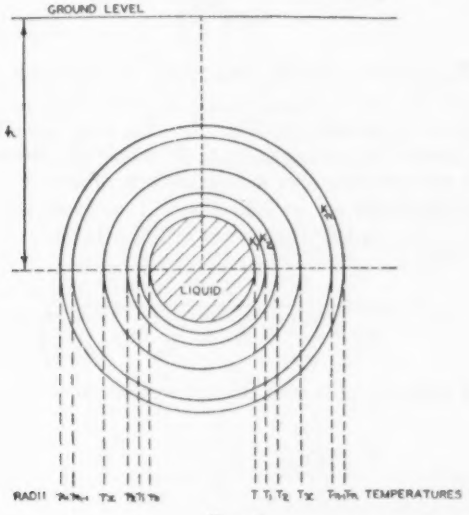

FIG. 1.

TEMPERATURE DISTRIBUTION IN A BURIED LAGGED PIPE.

radial temperature gradient in the liquid. In the most general case the pipe, of steel or of some other material, is coated with one or more layers of protective material of low thermal conductivity, so that the liquid can be considered as surrounded by a number, n, of concentric shells of differing thermal conductivities (K_1 to K_n). This is shown diagrammatically in Fig. 1, where r_0 and r_1 are the inner and outer radii of the pipe, and r_x is

the radius of the interface between the $(x-1)$th and xth layers of coating (that is, between the xth and $(x+1)$th shells).

Since the temperature fluctuations, if any, take place slowly, the radial rate of heat flow at any time is almost at its equilibrium value and is the same through each shell; also it equals that from the outermost shell to the soil. If this rate of flow per unit length of pipe is Q,

$$Q = \frac{2\pi K_1(T - T_1)}{\log_e\left(\frac{r_1}{r_0}\right)} = \frac{2\pi K_x(T_{x-1} - T_x)}{\log_e\left(\frac{r_x}{r_{x-1}}\right)} = \frac{2\pi K_n(T_{n-1} - T_n)}{\log_e\left(\frac{r_n}{r_{n-1}}\right)} \quad . \quad (1)$$

The rate of flow from the outer surface of the nth shell to the soil is given by Beale *et al*,[1] and is

$$Q = \frac{4\pi K(T_n - T_h)}{\log_e\left(\frac{h + \sqrt{h^2 - r_n^2}}{h - \sqrt{h^2 - r_n^2}}\right)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where T_h is the temperature of the soil at the depth h, remote from the pipe. In practice, equation (2) can almost always be replaced by the approximate equation

$$Q = \frac{2\pi K(T_n - T_h)}{\log_e\left(\frac{2h}{r_n}\right)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

which is valid as long as the fourth power of $\frac{r_n}{h}$ is negligible compared with unity.

The intermediate temperatures, T_1, T_x, T_n, may be eliminated from the series of equations (1) and equation (3) using the normal law for the summing of the numerators and denominators of equal ratios, and Q is then obtained in the form

$$Q = A(T - T_h) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where

$$A = \frac{2\pi K}{\log_e\left(\frac{2h}{r_n}\right) + K \sum_{x=1}^{x=n} \frac{1}{K_x} \log_e\left(\frac{r_x}{r_{x-1}}\right)} \quad . \quad . \quad . \quad (5)$$

The rate of heat flow per unit area of pipe surface is

$$Q' = \frac{Q}{2\pi r_1} = \frac{A}{2\pi r_1}(T - T_h) \quad . \quad . \quad . \quad . \quad . \quad (6)$$

so that the heat-transfer coefficient is

$$A' = \frac{A}{2\pi r_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The pipe exerts a frictional resistance to the flow of the liquid, and as a result the hydraulic pressure along the pipe falls continuously. The energy dissipated in overcoming this resistance appears as heat, which must be included in calculating the temperature of the liquid. To determine the rate of production of heat consider a cylinder of liquid of length dl travelling

along the pipe. If P is the pressure exerted on the rear face of the cylinder, that on the front face is $P + (dP/dl)dl$, so that the resultant force on the cylinder is $\pi r_0^2(dP/dl)dl$ in the forward direction (dP/dl is negative). In a short time dt the cylinder travels a distance $(G/\pi r_0^2)dt$, where G is the volumetric rate of flow. Hence the work done in moving the cylinder dl for a time dt is $G(dP/dl)dl \,.\, dt$. This work appears as heat, so that if H is the time rate of heat production from unit length,

$$Hdl \,.\, dt = (G/J)(dP/dl) \,.\, dl \,.\, dt \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where J is the mechanical equivalent of heat in the appropriate units. Hence,

$$H = GN/J \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The temperature distribution along the pipe can now be derived by considering the heat balance in the length dl of pipe. If the temperature increases by an amount dT in this length, the amount of heat absorbed in unit time is $\rho Gc \,.\, dT$ or BdT. The heat-balance equation is therefore

$$BdT = Hdl - A(T - T_h) \,.\, dl \quad . \quad . \quad . \quad . \quad . \quad (10)$$

This may be arranged as

$$dT/(T - T_\infty) = -(A/B)dl \quad . \quad . \quad . \quad . \quad . \quad (11)$$

where T_∞ is given by

$$T_\infty = T_h + H/A \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Integration of equation (11) gives the temperature T at a distance L along the pipe in the form

$$T = (T_0 - T_\infty)e^{-AL/B} + T_\infty \quad . \quad . \quad . \quad . \quad . \quad (13)$$

Here T_0 is the temperature of the liquid at the beginning of the length L. If the pipe is in thermal equilibrium with the soil, dT in equation (11) is zero, and the pipe temperature, T, becomes T_∞, which is therefore the equilibrium pipe temperature.

For normal calculation purposes equations (12) and (13) are more convenient in the forms

$$T_\infty = T_h + Y \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

and

$$(T_0 - T_\infty)/(T - T_\infty) = e^X \quad . \quad . \quad . \quad . \quad . \quad (15)$$

where

$$X = \frac{AL}{B} = k_x \,.\, \frac{2\pi KL}{\rho cG\left\{\log_e\left(\frac{2h}{r_n}\right) + K\sum_{x=1}^{x=n}\frac{1}{K_x}\log_e\left(\frac{r_x}{r_{x-1}}\right)\right\}} \quad . \quad (16)$$

and

$$Y = \frac{H}{A} = k_y \cdot \frac{GN}{2\pi K}\left\{\log_e\left(\frac{2h}{r_n}\right) + K\sum_{x=1}^{x=n}\frac{1}{K_x}\log_e\left(\frac{r_x}{r_{x-1}}\right)\right\} \quad . \quad (17)$$

Here, k_x and k_y are constants depending on the units employed.

These equations will be considered in more detail later, in connexion with the development of a simple calculation procedure.

In the experimental work detailed in this paper the length of line involved is, at most, about 20 miles, and equation (13) can be simplified by

expanding the exponential term and ignoring squares and higher powers of AL/B. The resulting equation for T after substitution for T_∞ from equation (12) is

$$T = T_0 - L/B\{A(T_0 - T_h) - H\} \quad . \quad . \quad . \quad . \quad (18)$$

so that over short distances T is a linear function of L. Equation (18) is used to obtain A from the observed data, except in 10-inch pipe, where measurements showed that the oil temperature had reached its equilibrium value, T_∞. The constant A in this case is obtained very simply using equation (12). Finally, K is calculated from A with the aid of equation (5), simplified by the following assumptions as to the conductivities of the pipes and their coatings.

The pipes examined had bituminous coatings with conductivities of the same order as that of the soil; also, they were made of steel, so that K_1 was very large compared with K. In these circumstances equation (5) may be used in the approximate form

$$K = (A/2\pi) \log_e (2h/r_1) \quad . \quad . \quad . \quad . \quad . \quad (19)$$

This approximation is equivalent to assuming that the coatings have been replaced by soil, and that there is no temperature gradient from the interior to the outside of the steel pipe.

Measurements in the Middle East.

Procedure.

The quantities required to calculate oil temperatures are flow data, pipe dimensions, coating and soil conductivities, and soil temperatures at the depth, h, of the pipe centre. In the present work the last two were obtained from measurements on existing pipes, using the theory given above. An alternative method,[3] in the absence of buried pipes, is to measure the temperature cycle in the soil at various depths over a period of a year. This cycle is roughly simple harmonic, and its amplitude decreases exponentially with increasing depth. The conductivity can readily be derived from such measurements, but they require at least a year, and, moreover, the conductivity obtained is an average value over the year. In fact, winter conductivities are normally higher owing to the presence of water. If a pipe is available, measurements take only a few days, and the result is applicable to the time of year at which they are taken.

In all cases the conductivity was derived from the constant A in equation (19), and A was obtained from the observations using either equation (18) or equation (12), depending upon the temperature distribution along the pipe. The measurements required were :—

Oil temperature,
Soil temperature,
Depth of pipe centre,
Internal and external radii of the pipe,
Length of pipe involved in the measurements,
Hydraulic pressure gradient,
Oil throughput,
Specific gravity and specific heat of the oil.

The pipes available for measurements were the 10-inch and 12-inch lines of the Iraq Petroleum Company and the 30-inch Trans-Arabian pipeline (Tapline).* Sketch maps of the areas concerned are shown in Figs. 2 and 3. Observations were made at stations K-1, K-2, and T-1 on the I.P.C. system and near Abqaiq on Tapline.

The soil at T-1 is typical of the Syrian desert. Similar country is found westwards along the pipeline route to beyond T-4, namely grey-brown desert steppe with occasional stony outcrops and wadis. The depth of soil varies from 6 inches up to a few feet, and beneath it is limestone rock. The soil at K-1 is similar in appearance, but it has been rendered fertile in parts by irrigation. At K-2 the pipeline passes through a wide belt of sand which is mostly compacted, but there is a small amount of drifting sand.

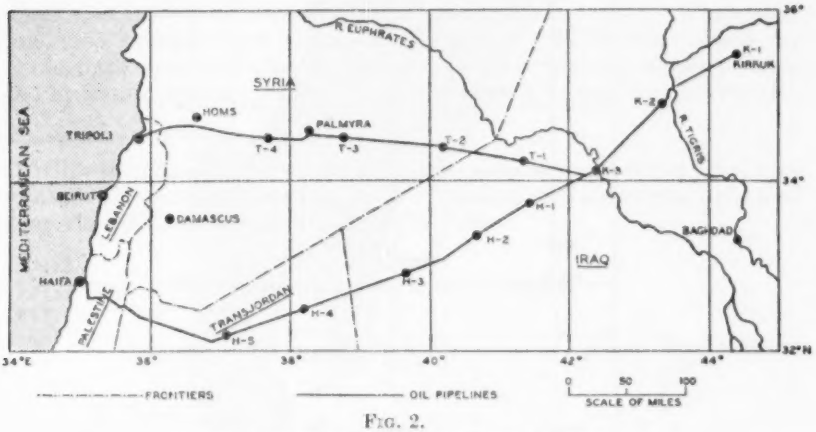

FIG. 2.

THE IRAQ PETROLEUM CO. PIPELINE SYSTEM.

The pipe upon which measurements were made in Arabia is buried in sand overlying limestone. To obtain sufficient depth the rock had been trenched by blasting, and the back-fill therefore consists of sand mixed with small rock fragments. The majority of the line, over rock and dry salt marsh, is built on the surface.

In order to obtain the oil temperature, the pipe was exposed and a bare thermocouple was pressed against a freshly cleaned area, using a pad of wood held tightly in position by a band of steel wire around the pipe. It was previously ascertained by calculation that the exposure of a short length of pipe in this way had no effect on the temperature downstream.

Soil temperatures were obtained by augering to the required depth at least 20 feet from the pipe and inserting a thermocouple bound to a wooden rod. Adequate thermal contact was ensured at the lower end by clamping the couple against a steel or brass disc which was rammed into the soil at the bottom of the hole. The top of the augered hole was stuffed with rags to hinder convection currents and the ingress of dust. At Abqaiq the presence of rock prevented augering to a sufficient depth, and a measure

* The length of pipe on which measurements were made was at that time part of the Tapline system, but is now administered by the Arabian-American Oil Company.

of soil temperature at the depth of the pipe centre was obtained by augering into the backfill of an empty pipe in the same neighbourhood.

The pipe depth was measured at all available exposed points, and where necessary additional holes were dug to expose the top of the pipe. In the soft sand at Abqaiq, satisfactory depth measurements were made by probing with a pointed steel rod. As expected, the pipe depth varied over the length used for each series of readings, but it can be shown that the effect of depth fluctuations is comparatively small, and a mean depth may therefore be taken in each case.

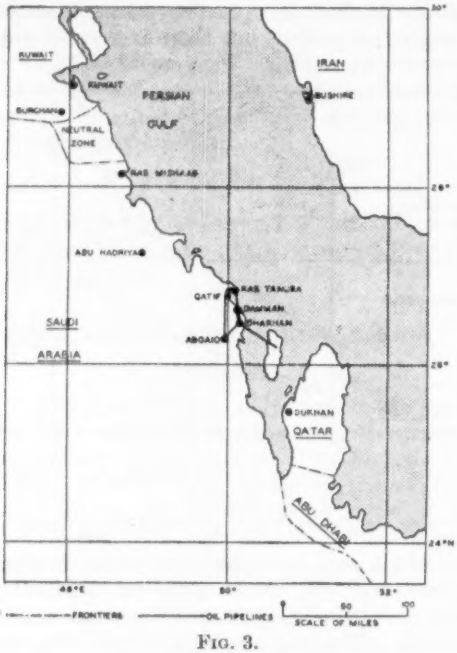

FIG. 3.

THE ARABIAN OILFIELDS.

Hydraulic pressure gradients were obtained in Iraq by measuring the pressure of the outgoing oil at a pumping station and assuming zero gauge pressure on arrival at the next station—the scheme adopted has atmospheric tanks "floating" on the line. The pressure drop thus obtained was corrected for the difference in elevation between the stations, assuming a height of 20 feet of oil in the reception tank at the downstream station. The calculation of hydraulic pressure gradients from this drop was complicated by the presence of lengths of nominal 10-inch pipe in addition to the 12-inch pipe. The Iraq Petroleum Company provided the pressure drop equivalent in accurate 10-inch pipe of nominal 10- and 12-inch pipes, and with these data the pressure gradients in both pipes were obtained.

At Abqaiq pressures were taken at two points near the ends of the length under test, and their difference was similarly corrected for elevation. All

pressure gauges were of the normal Bourdon type, and were calibrated immediately prior to use.

The remainder of the information required was provided by the operating staffs of the pipelines concerned, and every effort was made to obtain accurate data.

The procedure differed only in minor details at different sites. When the positions for temperature measurements on the pipe had been chosen the couples were installed and left for a day before any measurements were begun. Sets of pipe and soil temperatures were then taken on successive days. Since the oil temperature at the outlet from each station fluctuated during the day, it was necessary to time the readings so that one small plug of oil was followed through on each occasion. Two readings were taken at each thermocouple position, one a quarter of an hour after the other to check that there were no rapid fluctuations of oil temperature. The operating staffs maintained steady pumping rates at each station so that the throughput rates were almost constant. Pressure readings for determining the hydraulic-pressure gradient could therefore be taken when convenient.

Experimental Results.

While the measurements were being made, the contents of the pipes were either crude oil or, in some cases at K-2, gasoline, and the relevant physical properties of these liquids are shown in Table I.

TABLE I.

Physical Data on Throughput Liquids.

Material.	Specific gravity at 60° F (15° C).	Temperature coeff. of gravity per ° C.	Specific heat, cal/g, ° C.
Stabilized Kirkuk crude, plus residue	0·845	0·0007	0·48
Kirkuk gasoline . . .	0·710	0·0009	0·49
Stabilized Abqaiq crude .	0·833	0·0007	0·48

As an example of the derivation of the conductivity from the observed data, the readings taken at K-2 are dealt with in detail. At K-2, 10-inch pipe is used for 4·39 miles downstream from the station, and the rest of the line to K-3 is 12-inch pipe, a total distance of 84·05 miles. Measurements were made on a 10-mile length of 12-inch pipe. As stated above, the pipe was filled in some cases with Kirkuk crude, and in others with Kirkuk gasoline.

The constant A was derived, using equation (18), which gives

$$A = 1/(T_0 - T_h)\{H + B/L(T_0 - T)\} \quad . \quad . \quad . \quad (20)$$

so that in addition to temperature measurements, the quantities H and B/L are required. Taking account of units,

$$H = 5{\cdot}387 \times 10^{-10}\, GN \quad . \quad . \quad . \quad . \quad . \quad (21)$$

and

$$B/L = 3{\cdot}270 \times 10^{-7}\, \rho c G/L \quad . \quad . \quad . \quad . \quad (22)$$

where H is in cal/cm.sec., B/L in cal/cm.sec. ° C, G in Imp.gal/day, N in p.s.i/mile, c in cal/g. ° C, and L in miles.

The calculation of H and B/L is given in Table II, together with other relevant data.

TABLE II.

The Derivation of H *and* B/L *at K-2.*

	Crude.	Gasoline.
Mean throughput, G, Imp. gal/day	$1{\cdot}60 \times 10^6$	$1{\cdot}60 \times 10^6$
Density at 36° C, g/ml	0·830	0·691
Length of line, L, miles	10	10
B/L cal/cm. sec. °C	0·0208	0·0177
Hydraulic pressure gradient, N, p.s.i/mile	8·37	4·98
H, cal/cm. sec.	0·00721	0·00429
Internal pipe radius, r_0, in	6·045	6·045
External pipe radius, r_1, in	6·375	6·375
Speed of flow of oil, m.p.h.	2·54	2·54
Depth of pipe centre, h, in	27	27
Soil temperature at depth, h, T_h, °C	33·0	33·0

With pipe-temperature measurements, Table II provides all the data necessary to calculate A from equation (20), and the conductivity K is related to A by equation (19).

The final derivation of K for four different sets of measurements at K-2 is given in Table III.

TABLE III.

Calculation of Soil Conductivity at K-2.

Date.	Time at beginning of length.	Pipe contents.	Pipe temperature, °C.		A cal/cm. sec °C.	K cal/cm. sec °C.
			$T°$ (Beginning).	T (End).		
2.9.48	10·00	Gasoline	37·6	36·5	0·0052	0·0018
4.9.48	11·00	Gasoline	36·5	35·6	0·0058	0·0020
6.9.48	9·00	Crude	35·2	34·9	0·0061	0·0021
6.9.48	10·00	Crude	35·5	35·1	0·0062	0·0021

Taking the mean value of the figures in the final column of Table III, the soil conductivity at K-2 is 0·0020 cal/cm.sec. °C.

At all other places, only crude oil was encountered. The data, other than pipe temperatures, required for calculating K are listed in Table IV.

TABLE IV.

Experimental Data at K-1, T-1 and Abqaiq.

	K-1.	T-1.	T-1.	Abqaiq.
Nominal pipe diameter, in	10	10	12	30
Throughput, G, Imp. gal/day	$1{\cdot}64 \times 10^6$	$1{\cdot}58 \times 10^6$	$1{\cdot}58 \times 10^6$	$6{\cdot}40 \times 10^6$
Length of line, L, miles	10·72	7·96	9·84	7·27
B/L, cal/cm. sec. °C	0·0199	0·0260	0·0210	0·112
Hydraulic-pressure gradient, N, p.s.i/mile	19·7	19·4	8·37	0·815
H, cal/cm. sec.	0·0174	0·0165	0·00712	0·0028
Internal pipe radius, in	5·068	5·068	6·045	14·75
External pipe radius, in	5·375	5·375	6·375	15·00
Depth of pipe centre, h, in	31	25	25	41
Soil temperature at depth h, T_h, °C	33·0	28·4	28·4	31·0

TABLE V.

Pipe Temperatures at K-1, T-1, and Abqaiq.

Site . .	K-1.					T-1.				T-1.			Abqaiq.		
Pipe size, in .	10.					10.				12.			30.		
	Time at beginning.	Temperature, ° C.				Time at beginning.	Temperature, ° C.			Time at beginning.	Tempera- ° C.		Time at beginning.	Tempera- ° C.	
Length, miles		0	5·72	10·72	20·72		0	3·76	7·96		0	9·84		0	7·27
	11.03 on 23.8.48	40·4	—	40·0	—	06.00 on 7.8.48	33·6	33·7	33·7	06.00 on 7.8.48	33·7	33·1	10.30 on 8.10.48	54·1	50·8
	09.00 on 24.8.48	38·7	38·5	38·6	—	07.00 on 7.8.48	33·7	33·8	—	08.00 on 7.8.48	34·1	33·3	10.45 on 8.10.48	54·5	51·0
	11.00 on 25.8.48	40·3	39·8	40·1	—	08.00 on 7.8.48	34·0	—	34·1	07.00 on 9.8.48	34·0	33·5	10.15 on 9.10.48	53·3	50·1
	07.00 on 26.8.48	38·4	38·4	38·5	38·6	09.00 on 7.8.48	34·0	34·1	—	08.00 on 11.8.48	33·9	33·3	10.30 on 9.10.48	53·4	50·2
						07.00 on 9.8.48	33·8	33·8	34·0	11.00 on 12.8.48	34·0	33·4			
						08.00 on 11.8.48	33·7	33·8	33·9						
						11.00 on 12.8.48	33·6	33·8	34·0						

All available pipe temperatures at K-1, T-1, and Abqaiq are shown in Table V. It is interesting to note that in 10-inch pipe, the temperature is almost at its equilibrium value, T_∞. Thus, at K-1, the equilibrium temperature is 38·6° C, and this was maintained, within experimental error, for 10 miles on September 24, 1948. A steady rise to this figure was observed on September 26, and on the other days at later times there was a fall. At T-1, in 10-inch pipe, a small rise of temperature was found in all cases over a length of 7·96 miles, and the equilibrium value was 34·1° C. The thermal conductivities derived from the data in Tables IV and V are listed in Table VI, which, for completeness, includes the results for K-2 shown in Table III. For 12-inch and 30-inch pipes,

TABLE VI.

Conductivities Derived from the Temperature Measurements.

Site.	Type of soil.	Pipe diameter, in.	Pipe contents.	Time at beginning.	Conductivity, cal/cm sec. ° C.	Mean conductivity.
K-1	Desert steppe	10	Crude	11·00 on 23.8.48	0·0011	0·0011
				09·00 on 24.8.48		
				11·00 on 25.8.48		
				7·00 on 26.8.48		
K-2	Sand	12	Gasoline	10·00 on 2.9.48	0·0018	0·0019
				11·00 on 4.9.48	0·0020	
K-2	Sand	12	Crude	9·00 on 6.9.48	0·0021	0·0021
				10·00 on 6.9.48	0·0021	
T-1	Desert steppe	10	Crude	6·00 on 7.8.48	0·0010	0·0010
				7·00 on 7.8.48		
				8·00 on 7.8.48		
				9·00 on 7.9.48		
				7·00 on 9.8.48		
				8·00 on 11.8.48		
				11·00 on 12.8.48		
T-1	Desert steppe	12	Crude	6·00 on 7.8.48	0·0012	0·0012
				8·00 on 7.8.48	0·0014	
				7·00 on 9.8.48	0·0010	
				8·00 on 11.8.48	0·0012	
				11·00 on 12.8.48	0·0011	
Abqaiq	Sand in a limestone trench	30	Crude	10.30 on 8.10.48	0·0044	0·0044
				10.45 on 8.10.48	0·0045	
				10.15 on 9.10.48	0·0044	
				10.30 on 9.10.48	0·0043	

equations (19) and (20) were used to derive the soil conductivity and for 10-inch pipe it was obtained from the equilibrium temperature using equations (12) and (19).

Probable Errors.

There are three main sources of error in measuring the conductivities :—

(1) inaccuracies in the temperature measurements,
(2) errors in the values of H and B/L.

(3) the presence of a bituminous coating on the pipes, which was ignored.

The magnitude of the errors (1) and (2) can be deduced from equation (20), or from its equilibrium equivalent,

$$A = H/(T_\infty - T_h) \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

If ΔK and ΔA are the errors in K and A respectively due to errors $\Delta(T_0 - T_h)$ and $\Delta(T_0 - T)$ in $(T_0 - T_h)$ and $(T_0 - T)$, it follows that the maximum percentage error in K is

$$E = \frac{100\Delta K}{K} = \frac{100\Delta A}{A} = \frac{100\Delta(T_0 - T_h)}{(T_0 - T_h)} + \frac{100B}{L}\left(H + B\frac{(T_0 - T)}{L}\right)^{-1}\Delta(T_0 - T) \quad . \quad (24)$$

In the thermal equilibrium case,

$$E = \frac{100\Delta(T_\infty - T_h)}{(T_\infty - T_h)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

The maximum error in the temperature differences is 0·2° C, and using this value in equations (24) and (25), the maximum percentage error due to temperature errors may be calculated from the observed data. For the 10-inch pipe measurements using equation (25), it is $\pm$ 4 per cent; from equation (24), the error for the 12-inch is $\pm$ 20 to 35 per cent and for the 30-inch it is $\pm$ 7 per cent. The large maximum error for 12-inch pipe is due to the small temperature difference involved. In fact, the spread of readings on 12-inch pipe in Table VI is well within these limits, and the error in the mean due to temperature errors is not likely to be more than 10 per cent.

The errors in H and in B/L are difficult to estimate, but they should both be correct within $\pm$ 5 per cent. Assuming this figure, the values of the conductivities are likely to be in error by a percentage of the same order, due to this cause.

The coating consisted of a layer of bitumen about $\frac{1}{8}$ inch thick with a conductivity of, say, 0·0015 cal/cm.sec. °C.,[2] covered by bitumen-impregnated paper of conductivity about 0·0010cal/cm.sec. °C, with a thickness of $\frac{1}{16}$ inch. The effect of these layers can be estimated using equation (5), from which

$$K = \frac{A}{2\pi}\left\{\log_e\left(\frac{2h}{r_3}\right) + \frac{K}{K_3}\log_e\left(\frac{r_3}{r_2}\right) + \frac{K}{K_2}\log_e\left(\frac{r_2}{r_1}\right)\right\} \quad . \quad . \quad (26)$$

where r_2 and r_3 are the outer radii of the bitumen and paper layers and their conductivities are K_2 and K_3. The measured value of K depends on the pipe coating only through the logarithmic terms of equation (26). In the calculations given above, it was assumed that the approximate equation

$$K = \frac{A}{2\pi}\log_e\left(\frac{2h}{r_1}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

was sufficiently accurate. The error is readily determined by using the soil conductivities of Table VI in the right-hand side of equation (26) and

comparing the values of K obtained with those given in Table VI, and derived using equation (27). It may quickly be shown that the results are, at most, in error by about 2 per cent as a consequence of ignoring the presence of the coating.

Thus the mean conductivities shown in Table VI are likely to be in error by, at most, about 15 per cent, mainly due to errors in H, in B/L, and in the temperature measurements.

Discussion.

The conductivities obtained provide a means of assessing the validity of the theoretical analysis involved. Unfortunately, reliable data on soil conductivities are very scanty, but the Iraq measurements are in good agreement with the figures quoted by Keen [3] and by Beale, Hartley, Van Dyck, and Van Wyk.[1] Hence, the theory seems to be substantially correct for 10-inch and 12-inch pipes. The conductivity measured at Abqaiq was unusually high. This may have been due to inaccuracy of the theory when applied to 30-inch pipe, but more probably it was a result of laying the pipe in a rock trench. Rock has a much higher conductivity than soil,[3] so that the overall value for a pipe lying in a rock trench buried in sand would be higher than that of sand alone. It therefore seems fair to conclude that the existing analysis provides a reasonably good basis for temperature calculations on buried pipes with diameters up to, at least, 30 inches.

PART II.

The Calculation of Temperatures in Buried Lines.

The relationships required are equations (14) to (17). The values of k_x and k_y for various sets of units are shown in the following table.

Table VII.

Units Constants in Equations (16) *and* (17).

K.	G.	N.	c.	L.	Y.	k_x.	k_y.
Cal/cm. sec. ° C	Imp. gal/day	P.s.i/mile	Cal/g. ° C	Mile	° C	$1{\cdot}92 \times 10^{7}$	$8{\cdot}57 \times 10^{-11}$
Cal/cm. sec. ° C	U.S. gal/day	P.s.i/mile	Cal/g. ° C	Mile	° C	$2{\cdot}31 \times 10^{7}$	$7{\cdot}14 \times 10^{-11}$
Cal/cm. sec. ° C	Brl/day	P.s.i/mile	Cal/g. ° C	Mile	° C	$5{\cdot}49 \times 10^{5}$	$3{\cdot}00 \times 10^{-9}$
B.Th.U/ft. hr ° F	Imp. gal/day	P.s.i/mile	B.Th.U/lb ° F	Mile	° F	$7{\cdot}94 \times 10^{4}$	$3{\cdot}73 \times 10^{-9}$
B.Th.U/ft. hr ° F	U.S. gal/day	P.s.i/mile	B.Th.U/lb ° F	Mile	° F	$9{\cdot}53 \times 10^{4}$	$3{\cdot}11 \times 10^{-9}$
B.Th.U/ft. hr ° F	Brl/day	P.s.i/mile	B.Th.U/lb ° F	Mile	° F	$2{\cdot}27 \times 10^{3}$	$1{\cdot}31 \times 10^{-9}$

With the aid of Table VII, X and Y can quickly be evaluated for a given set of conditions, and T_∞ and $(T_0 - T_\infty)/(T - T_\infty)$ are obtained from equations (14) and (15). Antilog X may be read off from a table of natural logarithms or from a curve, and the requisite graph is given in Fig. 4. For a known value of the initial temperature, T_0, the temperature T at the end of a length L is then readily calculated.

Example of the Method of Calculation.

As an example of the calculation procedure, the temperature distribution is estimated below in a hypothetical 36-inch crude-oil pipeline from the

Persian Gulf to the eastern Mediterranean coast. Several projects of this type are in hand, and one of the difficulties to be surmounted is the cooling of pumping engines at desert pump stations. A possible method is to cool the engines with distilled water and to remove the waste heat by imparting it to the crude oil passing through in heat exchangers. In order to assess the applicability of the method it is necessary to know the temperature of the oil entering each station, so that the size of the heat exchangers can be calculated. The oil temperatures are therefore compared below with and without heat exchangers at pumping stations.

The data used in the calculations are :—

Throughput	= 600,000 brl/day
Sp. gr. of oil	= 0·830 at 110° F
Specific heat of oil	= 0·48 cal/g. ° C
Depth of pipe centre	= 58 in
External radius of pipe	= 18 in
Hydraulic gradient	= 20 ft/mile (7·2 p.s.i/mile)
Oil temperature at input	= 100° or 120° F
Total length of line	= 800 miles
Number of pumping stations	= 8
Distance between stations	= 100 miles
Rate of heat dissipation at each station	= 25×10^6 B.Th.U/hr
Thickness of bituminous coating	= 11/32 in
Thermal conductivity of the coating	= 0·001 cal/cm. sec. ° C

The most critical period for heat exchangers is in midsummer, when the thermal conductivity of the soil is at its lowest value, due to dryness. The heat dissipation to the soil is therefore a minimum and the oil temperature at any point a maximum. To calculate this temperature, the soil conductivity and soil temperature at 48 inches depth in summer are required. As a result of the measurements described earlier, with a knowledge of the terrain traversed, these quantities may be estimated, and are given in Table VIII.

TABLE VIII.

Thermal Data on the Pipeline Route.

Length, miles.	Conductivity, cal/cm. sec. ° C.	Soil temperature, ° F.
0–100	0·0020	92
100–200	0·0020	92
200–300	0·0020	92
300–400	0·0012	87
400–500	0·0012	82
500–600	0·0012	77
600–700	0·0012	72
700–800	0·0020	67

The constants X and Y can now be quoted as functions of K only, since the stations are equally spaced. The required values are, by substitution in equations (16) and (17).

$$X = 230K/\{\log_e 96 - \log_e 18{\cdot}34 + 1000K\,(\log_e 18{\cdot}34 - \log_e 18{\cdot}00)\}$$

$$Y = 0{\cdot}233\,\{\log_e 96 - \log_e 18{\cdot}34 + 1000K\,(\log_e 18{\cdot}34 - \log_e 18{\cdot}00)\}/K\ (^\circ\ \mathrm{F})$$

In deriving X the specific gravity has been taken as 0·830, its value at 110° F, irrespective of the actual oil temperature, because it has been found that the variations due to temperature changes are too small to affect the results. The values of X, Y, and $(T_0 - T_\infty)/(T - T_\infty)$, the last read from Fig. 4, are listed in Table IX.

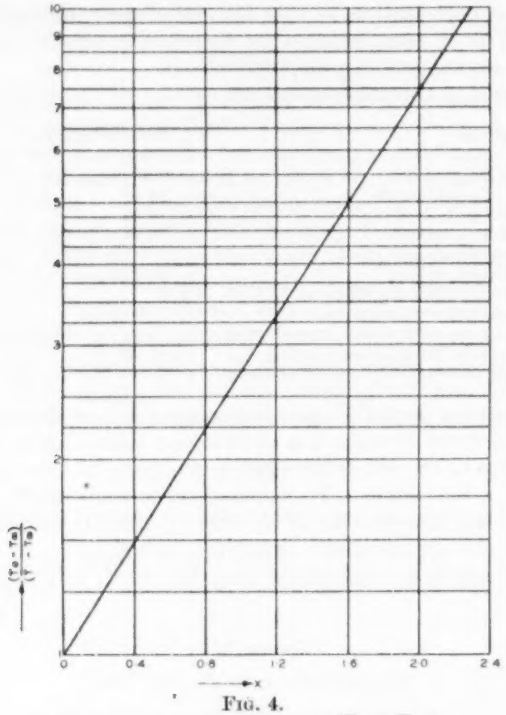

FIG. 4.

RELATION BETWEEN x AND $\dfrac{(T_0 - T_\infty)}{(T_0 - T_\infty)}$.

TABLE IX.

Calculation Constants.

Conductivity, cal/cm. sec. °C.	X.	$\dfrac{(T_0 - T_\infty)}{(T - T_\infty)}$.	Y (° F).
0·0012	0·165	1·18	32·5
0·0020	0·272	1·31	19·7

This table, with Table VIII, gives all the data required to calculate the temperature, T, on arrival at a station, given the temperature, T_0, at which the oil leaves the previous station. If heat exchange is complete, the temperature rise of the oil at each station is 7·5° F, so that incoming oil temperatures at each station can be calculated with and without heat exchange.

The arrangement of the calculations is shown in Table X, taking the case where the oil enters the pipeline from the first pumping station at 120° F.

TABLE X.

Temperature Calculations.

Length, miles.	T_h, ° F.	Y, ° F.	T_∞, ° F.	$\frac{(T_0 - T_\infty)}{(T - T_\infty)}$.	Oil temperature, ° F.			
					With heat exchange.		Without heat exchange.	
					T_0.	T.	T_0.	T.
0–100	92	19·7	111·7	1·31	120	118·0	120	118·0
100–200	92	19·7	111·7	1·31	125·5	122·2	118·0	116·5
200–300	92	19·7	111·7	1·31	129·7	125·5	116·5	115·4
300–400	87	32·5	119·5	1·18	133·0	130·9	115·4	116·0
400–500	82	32·5	114·5	1·18	138·4	134·7	116·0	115·8
500–600	77	32·5	109·5	1·18	142·2	137·2	115·8	114·8
600–700	72	32·5	104·5	1·18	144·7	138·5	114·8	113·2
700–800	67	19·7	86·7	1·31	146·0	131·9	113·2	106·9

In this table, T_0, the temperature on entering the length under consideration, is derived from T on the previous line by adding 7·5° F in the case of complete heat exchange, and zero for no heat exchange. The value of T in

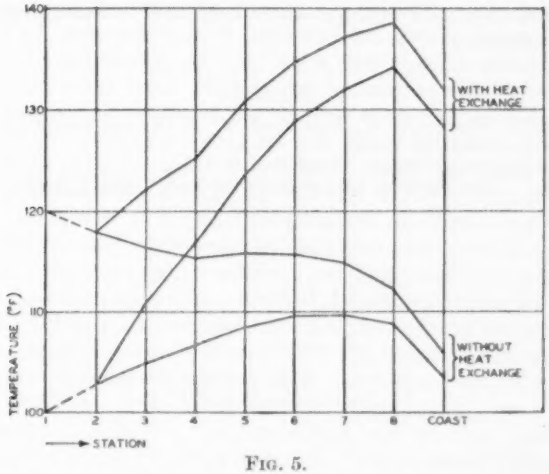

FIG. 5.

CALCULATED TEMPERATURES AT INPUT SIDE OF PUMPING STATIONS.

any row is derived from those of T_0, T_∞, and $(T_0 - T_\infty)/(T - T_\infty)$ in that row, while in the first row T_0 is the input temperature from the first station. T_h, Y, and $(T_0 - T_\infty)/(T - T_\infty)$ are read from Tables VIII and IX, and T_∞ is simply the sum of T_h and Y.

The temperature distribution is most readily shown by a graph giving the temperature at the input side of each station as a function of its position.

This is shown in Fig. 5 for starting temperatures of 100° and 120° F, with and without heat exchange.

It is evident from Fig. 5 that, for the conditions envisaged, if the waste heat at pumping stations is removed by heat exchange with the oil, its temperature in summer at the inlets to the pumping stations rises steadily as it travels westwards, reaching a maximum of 135–140° F at the eighth station, 100 miles from the Mediterranean. Similar, more detailed calculations confirm this trend, and suggest that the heat-exchanger method of cooling the pumping engines is likely to be difficult in summer, although in winter higher soil conductivities and lower soil temperatures make it quite practicable.

This calculation has been given simply as an example. It will be appreciated that the method is applicable not only to oil pipelines but also to any buried pipe carrying liquid in turbulent flow.

Acknowledgments.

The writer wishes to thank the chairman of the Anglo-Iranian Oil Co. Ltd. for permission to publish this paper. In the course of the experimental work the facilities of the Iraq Petroleum Co. Ltd., the Trans-Arabian Pipeline Co. Ltd., and the Arabian-American Oil Co. Ltd. were used very extensively, and this opportunity is taken of acknowledging the assistance and advice which was so freely given by their staffs. A high proportion of the practical work was carried out by Iraq Petroleum and Trans-Arabian Pipeline personnel, and without their help the measurements would not have been possible.

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FURTHER RESEARCHES ON THE DETERMINATION OF THE CHEMICAL COMPOSITION OF OIL SHALES.*

By T. E. Dancy and V. Giedroyc.

Summary.

The removal of mineral matter from the Ermelo Torbanite (South Africa), St Hilaire oil shale (France), and Kimmeridge oil shale (Dorset) was studied using a chemical and a physical method. The former, using mineral acids, caused some attack of the kerogen, and this effect was studied in some detail. The physical method, employing a grinding process with oil, was unsuitable for the Kimmeridge, but was used for the indirect determination of the composition of the kerogen of the other samples. These compositions were compared with those calculated from the chemically enriched † shales.

Introduction.

Oil shales contain widely varying amounts of mineral matter, ranging from almost 100 per cent to as little as 1 to 2 per cent, and this material introduces difficulties in the determination of the true ultimate composition of the kerogen, as the organic matter is called. In a direct ultimate analysis of a high-ash oil shale, two large errors in the calculation of the composition of the kerogen are immediately obvious. The first, in the carbon, due to the presence of carbonate can be corrected for after a separate determination of the carbon dioxide evolved when the shale is treated with acid. The second and main error, that in the hydrogen, cannot be determined directly. A large proportion of the mineral matter of most oil shales consists of clays of various compositions and other hydrated minerals which contain as much as 10 per cent of " combined water " or water of hydration. This water is not removed by heating *in vacuo* at 105° C but, on combustion of the oil shale at 800° C in the determination of carbon and hydrogen, it is driven off to be collected, weighed, and therefore included in the value for hydrogen. In the past, attempts have been made to correct for this water, but it has been shown that most of the water in clays is only expelled at above 600° C,[1] at which temperature the kerogen will be entirely decomposed. It is therefore clear that only after the chemical removal of mineral matter, or the physical separation of it, from the kerogen can the true ultimate composition of the latter be determined.

A three-stage process for the removal of the mineral matter from oil shales, developed in the Fuel Laboratories of the Imperial College,[2] consists of :—

(1) Treating the shale with 1 : 1 hydrochloric acid which removes carbonates of Ca, Mg, Fe, etc., and sulphates.

(2) Treating the residue with mixed hydrochloric and hydrofluoric acids to decompose and dissolve silicates. The material is then boiled

* Part of thesis for degree of Doctor of Philosophy in the University of London.

† The term " enriched " in this paper is synonymous with " de-ashed " in previous work on this subject.[3, 4, 7, 8, 11]

with sodium carbonate solution to decompose any acid-insoluble complex fluorides.

(3) Treating the remaining material with zinc dust and hydrochloric acid to remove iron pyrites.

It was found that the "ash" of many oil shales could be reduced to below 2 per cent without difficulty, and it was shown that the process had only a slight influence on the composition of the kerogen. Nevertheless, this procedure could introduce errors, especially if the kerogen had any tendency to decompose.

The physical removal of mineral matter has been extensively studied in connexion with coals, but the usual methods have been seldom applicable to oil shales, since their mineral components are usually finely divided and intimately mixed with the organic matter. F. W. Quass [3] worked out a method based on the Trent amalgamation process, in which a sample of torbanite was ground with oil and water. The organic material tended to form a paste with the oil, while the mineral matter remained in suspension in the water. Basak and Himus [4] modified this process and found it suitable for concentrating the organic matter of coals with high "ash." By carrying out the process in a stepwise fashion they found that, since no part of the mineral matter was removed preferentially, the plots of per cent carbon against per cent ash, and per cent hydrogen against per cent ash for the fractions from any one sample lay on straight lines. By extrapolation to zero per cent ash, the carbon and hydrogen of mineral free coal could be determined, and by extrapolating the carbon line to zero per cent carbon the ratio of mineral matter to ash could be calculated. This process seemed suitable for the separation of kerogen from much of its associated mineral matter, and by carrying out the process in a stepwise manner it could give an independent method of determination of carbon and hydrogen.

Experimental.

The magnitude of the errors involved in the calculation of the true ultimate composition of kerogen of the Ermelo torbanite (South Africa), the St Hilaire (France), and Kimmeridge (Dorset, England) oil shales was estimated by a comprehensive comparison of the compositions of the original and treated samples. Where possible the physical method of Basak and Himus [4] was also used, and the results obtained were compared with those determined after the chemical treatment. Since the kerogen of the Kimmeridge was known to be very easily oxidized and probably rather unstable, the effect of mineral acids and of alkalis was studied in some detail.

Chemical Removal of Mineral Matter.

Ermelo Torbanite.

The Ermelo torbanite was enriched by mineral acid treatment. The boiling with sodium carbonate was omitted, since a very small amount of kerogen was dissolved by it; this was indicated by the slight yellow coloration of the solution, but the quantity extracted was too small for quantitative estimation. The ultimate compositions of the original and enriched oil shale are recorded in Table I. It is seen that the ash was reduced to

TABLE I.

	Ermelo.				St Hilaire.				Kimmeridge.			
			Kerogen.				Kerogen.				Kerogen.	
	Original.	Enriched.	Cal. on ash-free basis from enriched.	Cal. on mineral matter-free basis from original.	Original.	Enriched.	Cal. on mineral matter-free basis from 14·95% ash material.	Cal. on mineral matter-free basis from original.	Original.	Enriched.	Cal. on ash-free basis from enriched.	Cal. on mineral matter-free basis from original.
Carbon	42·03	78·00	79·80	80·80 §	29·92	66·90	84·50	85·0 §	39·45	68·20	68·80	68·50
Hydrogen	4·34	7·00	7·16	7·30 §	3·11	6·17	7·79	7·75 §	4·30	7·13	7·20	7·17 ‖
Nitrogen	0·90	1·52	1·57	1·74	0·48	1·00	1·26	1·39	0·88	1·34	1·35	1·53
Sulphur, organic	0·32	—	0·60 *	0·62 *	0·38	—	1·07 *	1·10 *	5·40	9·32	9·40	9·37
Oxygen + errors	—	9·90	10·12	9·54	—	—	5·38	4·76	—	12·56	13·25	13·43
Ash	45·53	2·26	—	—	62·24	14·95	—	—	39·6	0·91	—	—
Carbon as carbonate	0·06	—	—	—	0·75	—	—	—	0·16	—	—	—
Sulphur, total	0·58	1·32	1·35	—	4·85	10·07	—	—	7·05	9·86	—	—
Carbon/hydrogen	9·7	11·14	11·14	10·02	9·6	10·85	10·85	10·6	9·20	9·56	9·56	9·56
Mineral matter/ash	1·06 ‡	—	—	—	1·05 ‡	—	—	—	1·07 †	—	—	—

* Calculated from organic sulphur in original shale.
† Calculated from the individual mineral matter/ash ratios for the HCl and HF treatments.
‡ Determined from zero % C intercept—see Fig. 3.
‡‡§ Carbon and hydrogen values taken from zero % ash intercepts—see Fig. 3.
‖ Calculated from C/H ratio of enriched sample—see Table IV.

2·26 per cent by this process, and thus the calculation of the composition of kerogen on an ash-free basis did not involve serious error.

Since all the nitrogen in the original shale may be assumed to be part of the kerogen, it is evident that there has been a loss of nitrogen during the acid process. This loss of 8·2 per cent of the nitrogen originally present (*i.e.*, 0·14 per cent on the original shale) could no doubt be attributed to the removal of organic basic substances by the prolonged acid treatment (Table II).

TABLE II.

	Ermelo.	St Hilaire.	Kimmeridge.
Nitrogen in original . . .	0·90	0·48	0·88
Nitrogen expected in kerogen .	1·71	1·38	1·53
Nitrogen found in kerogen . .	1·57	1·26	1·35
Nitrogen extracted :			
Per cent of kerogen . .	0·14	0·12	0·18
Per cent of nitrogen . .	8·2	8·73	11·8

Total sulphur was determined in the original and in the enriched shale by the Eschka method,[5] and pyritic plus sulphate sulphur was determined in the original. The organic sulphur [= total −(pyritic + sulphate)] should be the same in both substances with respect to carbon, but there had been an apparent gain with 0·75 per cent of sulphur in the enriched material. This may be attributed to the incomplete removal of pyrite by the zinc and hydrochloric acid treatment. Contrary to a statement by Cave,[6] it was shown in this laboratory that this process is not necessarily quantitative, and thus the iron found in the small amount of ash after the exhaustive chemical treatment cannot be assumed to have been in organic combination,[7] but was undoubtedly derived from pyrite which had been incompletely removed. The inefficiency of the zinc and hydrochloric acid treatment for the removal of pyrite was emphasized by the behaviour of the St Hilaire oil shale to this process.

St Hilaire.

This shale was treated in the same manner as the Ermelo, but though the ash was reduced to 14·95 per cent by the first two processes, five successive treatments with zinc and hydrochloric acid failed to reduce it further than 12·2 per cent. Analyses of the original shale and the " 14·95 per cent ash " material are shown in Table I, and the composition of the kerogen was calculated in the following manner. The partially enriched material contained 10·07 per cent (total sulphur) − 0·85 per cent (organic sulphur) = 9·22 per cent (inorganic sulphur), and its ash contained 53·9 per cent of iron. Thus, the percentage of iron calculated on the sample is (53·9/100) × 14·95 = 8·06 per cent Fe, and 8·06 per cent Fe is equivalent to 11·52 per cent Fe_2O_3. Assuming the 8·06 per cent of iron was entirely derived from pyrite, it would require 9·2 per cent of sulphur, which is actually present in the mineral matter.

Also, the per cent ash other than that derived from pyrite = 14·95 − 11·52 = 3·47 per cent, and this was assumed to have a mineral matter

to ash ratio = 1·05 per cent.* Thus percentage of mineral matter other than pyrite = 3·47 × 1·05 = 3·64 per cent.

$$\therefore \text{ Total mineral matter} = \underset{\text{Surplus}}{3{\cdot}64} + \underset{\text{Iron}}{8{\cdot}06} + \underset{\text{Sulphur}}{9{\cdot}22} = 20{\cdot}92 \text{ per cent.}$$

Using this calculated value for the true amount of mineral matter in the " 14·95 per cent ash " substance, the calculated composition of the kerogen of the St Hilaire was obtained (Table I). It is seen that, as with the Ermelo, there has been a small loss of nitrogen after the acid treatment (Table II).

It should be mentioned that the pyrite was easily removed from the St Hilaire by nitric acid but, like the Ermelo,[8] considerable nitration of the kerogen occurred. Final treatment with 1·13 sp. gr. nitric acid gave a substance with only 0·82 per cent ash, the nitrogen was 2·31 per cent, whereas that calculated from the original nitrogen should be 1·33 per cent, and thus the removal of pyrite by nitric acid could not be used on this shale without considerable alteration of the kerogen.

Kimmeridge Oil Shale.

Since the kerogen of this shale was liable to be affected by vigorous chemical reagents, each stage of the enriching process was followed quantitatively. Samples of the shale, the original composition of which is shown in Table I, were digested with 1 : 1 hydrochloric acid on a steam-bath for 2 hours and 48 hours respectively. The residues were filtered off, and aliquot portions of the filtrates were evaporated to dryness and analysed for carbon. The results showed that while little carbon was dissolved, after 2 hours, 0·45 per cent was removed after the prolonged treatment. The remainder of the filtrate from the latter was made alkaline with potassium hydroxide and steam distilled. A distinct odour of pyridine could be detected, and the residue, obtained after evaporating the distillate which had been collected in dilute hydrochloric acid, was very small. On redistillation with potassium hydroxide, ammonia was evolved initially, and upon further heating there was an odour of pyridine, but the few drops of clear distillate had not this smell and darkened on standing (cf. aniline). The yield was insufficient to allow identification, but it is certain that a small portion of the kerogen consisted of basic organic substances which were extracted during the acid treatment.

The action of hydrofluoric acid on the kerogen could not be determined directly, since much of the products are volatile, and therefore an indirect method was adopted based on the work of Basak and Himus.[4] The results of stepwise chemical treatment as a whole could not be expected to give a straight line when per cent carbon was plotted against per cent ash, since during each stage of the process different mineral components were removed. Nevertheless, if only the stage during which silica and silicates were removed was considered, deviation from a straight line should be small, providing there was no reaction between hydrofluoric acid and the kerogen. The results obtained from the stagewise hydrofluoric acid treatment are

* Zero per cent C intercept of per cent C/per cent ash line = 95 per cent ash (see Fig. 1).

shown in Table III, and Fig. 1 shows that a straight line is followed closely down to 1·5 per cent ash, but some change in the composition of the kerogen must occur beyond this stage. This deviation was probably caused by oxidation of the kerogen, and not due to attack by the hydro-

TABLE III.

Hydrofluoric Acid Treatment.

	Stages.				
	I.	II.	III.	IV.	V.
	Per cent.				
Carbon	61·22	65·80	67·14	67·16	67·05
Hydrogen	6·44	6·80	7·01	7·03	6·99
Ash	10·32	3·63	1·54	1·30	1·23

fluoric acid, otherwise no part of the curve would be a straight line. It is evident that by removing the mineral matter beyond a certain limit, its protecting influence was reduced and the kerogen became more liable to oxidation.

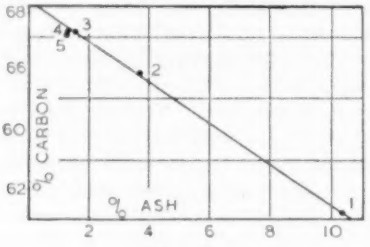

FIG. 1.

Further proof of this was obtained after two more experiments in which the ash was reduced to 1·13 and 0·91 per cent respectively by means of the three-stage process (Table IV). In the first case the change in carbon

TABLE IV.

Composition of Kimmeridge Oil Shale at Different Stages of Enriching Process.

	Original.	HCl I.	HCl II.*	HF I.	HF II.	HF III.	HF IV.	HF V.†	Zn + HCl I.	Zn + HCl II.
Carbon . . .	9·45	45·40	45·35	61·22	65·80	67·14	67·16	67·05	67·30	68·20
Hydrogen . . .	4·30	4·80	4·81	6·44	6·80	7·01	7·03	6·99	7·03	7·13
Ash	39·60	32·50	31·88	10·32	3·63	1·54	1·30	1·23	1·13	0·91
C/H	9·22	9·45	9·42	9·51	9·68	9·56	9·56	9·60	9·56	9·56
C, on ash free basis .	65·40	67·22	66·6	68·32	68·38	68·15	68·1	68·0	68·03	68·80
C, on mineral matter-free basis . . .	68·50	69·20	68·4	68·73	68·50	68·20	62·20	68·0	68·28	68·82
H, on ash-free base .	7·12	7·12	7·07	7·17	7·06	7·12	7·12	7·09	7·12	7·20
H, on mineral matter-free basis . . .	7·40	7·32	7·26	7·22	7·08	7·14	7·12	7·09	7·12	7·20
Mineral matter/ash ratio	1·132	—	—	—	1·06	—	—	—	—	—

* Sample treated with HCl for 48 hours. † Sample previously treated with HCl for 48 hours.

content was out of proportion to the amount of mineral matter removed, but this was not true in the second experiment during which special pre-

cautions were taken to minimize the possibility of oxidation of the kerogen. Throughout the whole process the temperature was not allowed to rise above 60° C. During the hydrofluoric acid treatment the sample was never evaporated to dryness, and in the final stage the zinc–kerogen mixture was diluted with water before the addition of the hydrochloric acid. Finally, the sample was dried in a vacuum desiccator at room temperature to a moisture content of 5·8 per cent and analysed. The results of the analysis calculated on the dry kerogen showed that oxidation was almost negligible.

The analytical data from the stagewise acid treatments are assembled in Table IV. The weight of shale and per cent ash were determined at each stage of the process, and since the loss in weight of any one sample quantitatively represented the removal of mineral matter, the mineral-matter-to-ash ratio could be calculated. The carbon and hydrogen were calculated on " ash-free " and on " mineral-matter-free " bases at each stage of the de-ashing process, and the values obtained were plotted against their respective ash contents (Fig. 2). This gives a comprehensive picture

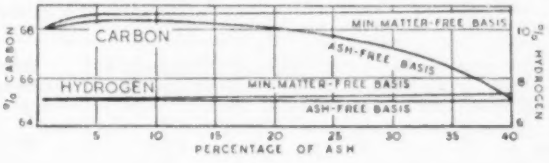

FIG. 2.

of the changes in composition of the kerogen. The carbon line on an " ash-free " basis rises with decrease of ash content, until at a certain stage of de-ashing it suddenly falls, indicating an apparent loss of carbon. The change in slope of this line represents the alteration in composition of the mineral matter removed. The other carbon line, calculated on a " mineral-free " basis, would be parallel to the per cent ash axis if there was no change in composition of the kerogen, and thus its slope gives an indication of the removal of organic material during the early stages of the chemical process. As in the first curve, there is a sudden drop beyond the " critical ash content " (see Fig. 1). The hydrogen lines are similar, but clearly the alteration in slopes is not as great.

Carbon-to-hydrogen ratios calculated at the various stages of the process (Table IV) give unexpected results. After hydrochloric acid treatment the ratio shows a marked increase, while after hydrofluoric acid treatment only a small increase. This indicated that there was more water of hydration in the minerals soluble in hydrochloric acid than in the clay materials. Also it is seen that most of the hydrated silicates are removed during the first hydrofluoric acid treatment. The fact that the C/H ratio remained constant during the later stages of the process (*i.e.*, after all hydrated material had been removed) may be regarded as further evidence of the lack of attack of the kerogen by hydrofluoric acid or by the final zinc and hydrochloric treatment. The results indicated that, contrary to what has been assumed, most of the water of hydration in this shale is not in the clay material.

Influence of Alkali.

Initial experiments showed that a portion of the kerogen was dissolved by alkali and, therefore, washing with sodium carbonate solution was not employed during the chemical-enriching process. The amount soluble appeared to be much greater than that obtained from either the Ermelo or St Hilaire, and therefore this effect was investigated further.

After treating a sample of the Kimmeridge oil shale with hydrochloric acid it was refluxed with 10 per cent potassium hydroxide solution with the top of the condenser closed by a soda-lime tube. The sample was then filtered off, thoroughly washed with hot distilled water, dried, and analysed for carbon, hydrogen, and ash. A portion of the filtrate was acidified with hydrochloric acid, boiled, evaporated to dryness, and analysed for carbon; another portion of the filtrate was analysed for carbon dioxide, and a blank determination on the potassium hydroxide was taken into account. The results, shown in Table V, indicated that not only did this treatment remove

TABLE V.

	Composition of Kimmeridge.	
	Before treatment.	After treatment.
	Per cent.	
Carbon	45·40	49·15
Hydrogen	4·80	5·48
Ash	32·50	25·40
Original carbon dissolved:		
As CO_2	—	0·53
As humic acids	—	6·06

some mineral matter from the shale but also the alkali extracted some humic acids which were no doubt formed from insoluble humins with the simultaneous evolution of carbon dioxide. Since the Kimmeridge oil shale is known to be very susceptible to oxidation, it is quite likely that the prolonged boiling in the presence of air caused the formation of "regenerated humic acids" which had not originally existed in the shale. Thus, separate determinations of humic acids by two methods were made on the original shale. The estimation by Erdman's [9] method gave 0·37 per cent, while that of Fuchs [10] gave 4·2 per cent for the amount of humic acids in the Kimmeridge, but since the values obtained by both these methods depend on different empirical assumptions, they cannot be expected to agree. Nevertheless, either method may be used for comparing the humic acid content with that of other carbonaceous materials.

Physical Separation of Mineral Matter.

Samples of the Ermelo torbanite, St Hilaire, and Kimmeridge oil shales were ground individually with gas oil (sp. gr. 0·87) and water in a ball mill in the manner described by Basak and Himus.[4] After 24 hours' treatment only the Ermelo kerogen formed a paste with the oil and left its mineral matter in suspension in water. The St Hilaire did not separate into com-

ponents even after 40 hours, but a separation was obtained by pouring the oil shale/oil/water mixture into benzene, when enriched organic material plus oil floated in the benzene layer, leaving almost pure mineral matter in suspension in the water layer. After 300 hours the kerogen of the St Hilaire did eventually form a paste with the oil, but this was no easier to separate than the mixture obtained after 40 hours. The Kimmeridge showed no signs of separating into components with any type of oil, even after grinding for several hundred hours. This could probably be attributed to the fact that the mineral matter of the shale formed a plastic mass early in the grinding process and prevented any further mixing or breakdown of the components of the shale.

The concentrated organic material and the mineral matter obtained from the Ermelo and St Hilaire by the grinding process were analysed for carbon, hydrogen, and ash. These values, together with those of the original shales, are shown in Table VI and plotted in Fig. 3. The points

TABLE VI.

		A.	B.	C.	D_1.	E.	F.
				Per cent.			
Ermelo	Ash	13·45	45·53	91·54	50·50	—	—
	C	69·50	42·03	1·91	37·75	81·0	79·8
	H	6·35	4·34	0·68	3·60	7·3	7·16
		A.	B.	C.	D_2.	E.	F.
				Per cent.			
St Hilaire	Ash	33·60	64·50	75·55	(19·87)	—	—
	C	54·60	29·90	17·60	66·90	85·0	84·5
	H	5·27	3·11	1·66	6·17	7·75	7·79

A. Concentrated organic matter after grinding with oil and water.
B. Original oil shale.
C. Concentrated mineral matter after grinding with oil and water.
D_1. " Sinks " after centrifuging original Ermelo (100 mesh) with 1·45 sp. gr. CCl_4/C_6H_6.
D_2. C and H from chemically enriched substance (14·95 per cent ash). Ash determined from calculated mineral matter (20·92 per cent) by applying mineral matter/ash ratio from curve (1·05). Thus, " calculated ash " = 20·92/1·05 = 19·87 per cent.
E. From graph Fig. 3, by extrapolation to zero per cent ash.
F. C and H calculated from chemically enriched oil shale—see Table I.

obtained lie quite close to straight lines, and therefore it can be assumed that the mineral matter removed from the shale during the process is of the same composition as both that remaining in the portion rich in kerogen and that in the original shale. When these curves are extrapolated to zero per cent ash the values for the carbon and hydrogen intercepts are those of the mineral-free kerogen. These are seen to differ only slightly from the compositions calculated from the chemically enriched shales (see also Table I). Extrapolation of the carbon lines to zero per cent carbon gives a value for the per cent of ash derived from 100 per cent mineral water, *i.e.* (ash/mineral matter × 100).

Further points were obtained on the carbon and hydrogen lines of the Ermelo by analysing the " sinks " after a finely ground sample of the shale

had been centrifuged in a mixture of benzene and carbon tetrachloride with sp. gr. of 1·46. Thus, it is probable that there was no largely preferential concentration of a particular part of the mineral matter, but the amount of separation was only small. The St Hilaire could not be separated at all by "float and sink"; however, further points on the carbon and hydrogen lines were obtained by assuming that the ash in the "14·95 per cent ash" material was derived from the mineral matter as a whole rather than from pyrite only. Then, using the mineral/ash ratio = 1·05 (read from the curve), 20·84 per cent of mineral matter should give 20·84/1·05 = 19·8

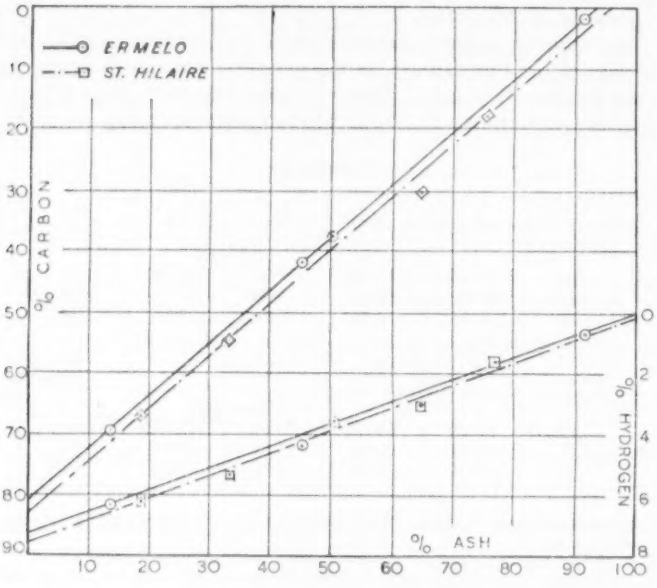

FIG. 3.

per cent of ash, and thus 66·9 per cent C and 6·17 per cent H with 19·8 per cent ash should lie on the lines if there had been no alteration of the kerogen after the acid treatment. These points are seen (Fig. 3) to be very close to the curves.

CONCLUSIONS.

From the results of the chemical enriching of the Ermelo, St Hilaire, and Kimmeridge oil shales, it was possible to draw the following conclusions:—

1. Hydrochloric acid extracted a small portion of the kerogen of these shales in the form of organic bases, but otherwise acid treatment does not appearently attack the kerogen itself. Changes which do occur in the Kimmeridge may be attributed to oxidation.

2. Boiling with sodium carbonate solution should be avoided, since alkali-soluble materials might be formed by oxidation during the treatment.

3. Treatment with zinc and hydrochloric acid does not remove pyrite quantitatively, and since the kerogen of oil shales is often nitrated by nitric acid, this method of separation could not be used. Thus, the mineral-free composition of the kerogen from pyrite cannot be separated, and can be determined only after the estimation of pyritic iron in the ash.

4. The physical removal of mineral matter, where applicable, and the graphical interpretation of results is the most satisfactory method for the determination of the true percentage carbon and hydrogen in the kerogen. However, this process will not separate kerogen from inorganic matter, which forms a plastic mass with water, and further research is necessary before its use can be extended.

5. No method generally applicable to the removal of mineral matter from oil shales can be described, and variations must be made to suit individual samples.

ACKNOWLEDGMENT.

The authors wish to thank Dr G. W. Himus, under whose direction this work was carried out, for his interest and helpful advice.

Imperial College of Science and Technology,
London, S.W.7.

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CALGON.

On page 233 of the April 1950 issue of the *Journal* reference was made to "Calgon." This word is the registered trade mark of Messrs Albright and Wilson Ltd. for their sodium metaphosphate and is not, as such, a chemical name.

CORRESPONDENCE.

"*Environmental Cancer and Petroleum.*"

To the Editor, *Journal of the Institute of Petroleum.*

SIR,

I have read with much interest the excellent paper by Colonel Auld in the April 1950 issue of your *Journal.*

As to the protection given to work-people, it is peculiar from an historical point of view that long before 1922, when Drs Southam and Wilson drew attention to the number of cases, textile machinists in Great Britain made a special non-splash spindle bolster, and some of these were manufactured for Messrs. J. Ashworth & Co. Ltd., Astley Bridge, Bolton, who still have them on their mules. Why they were made if it was not for the protection of workers I do not know, and why their manufacture was discontinued is a mystery.

On the question of cleanliness, I have good reason to believe that our people have done as much as could be expected of them. It should be borne in mind that "excessive" washing will remove the natural oils from the skin. Dr Leitch informed a meeting held in Manchester many years ago that, after washing, the skin should be smeared with lanolin to replace the natural oil washed away. We have advised our members to bath frequently and to smear the skin with lanolin.

The Departmental Committee in January 1946 recommended that baths should be provided. I do not know just how many mills have acted upon the recommendation, but I can assure you they are few.

On the question of medical inspection we have never raised any objection. Indeed one firm, Messrs Barlow & Jones Ltd. embarked upon it twenty years or more ago, and it had the support of the Union. The question of medical examination was discussed with the Employers' Association as long ago as 1925, and the only objection raised was by the Employers' representatives, who objected to being called upon to pay for it. They expressed the view that the service should be provided by the National Health Insurance Department. We still welcome the medical examination recommended by the Departmental Committee in their report of May 1945.

With regard to the Manchester Committee's specification of 1934, we welcomed it at the time as a step in the right direction, particularly as it came from such a responsible body, and as laymen we accepted it as a solution. In fact, until 1945 we looked upon it as the most effective oil known. Then Mr Paton of the Manchester Oil Refinery Ltd. informed me of the "technical white oil" they were marketing under the name of "Puremor." On receipt of this information, and after correspondence

with Dr Twort, I raised the subject with the Factory Department, and this resulted in the meeting which you attended in Manchester in 1946, when you very generously said you could make the oil available after an examination of the claims made for it.

Referring to the war years, when oils were pooled, it was quite by accident in 1943 that we as a Union discovered that the Manchester Committee formula had been discontinued, and it was quite a shock to us at the time. As soon as it was discovered we asked the Employers' Association to go along with us to the Ministry. At the onset they expressed their willingness to join with us in this approach but later, for some reason never disclosed, they declined, and we went alone. We were informed that the oils could be made available to comply with the Manchester formula, but at the same time it was pointed out that certain oils by themselves complied with the formula but when mixed failed to do so. At the time the only available oils which were regarded as " safe " or least carcinogenic were those which conformed to the Manchester specification, and we did all we could to have the formula re-introduced. We continued in our efforts to ensure that oils conformed to the Manchester formula until 1945 when, as stated earlier, the Manchester Oil Refinery Ltd. produced their " Puremor " oil. From that time our aim has been to get these technical white oils introduced.

Two meetings have been held and resulted in the specification mentioned on p. 247. I note you gave your address on January 17 last. The specification has not yet come before the Committee, as I understand from Dr Murray it has been found necessary to prepare the formula for the oil trade and industry in such terms as will ensure the oils being non-carcinogenic.

I have written at some length on some of the more important features of the subject, and there is still one about which I must make some comment. The reference on p. 248 to the adoption of some other form of spinning less exacting makes me (if you will excuse the term) bristle somewhat. Mules are gradually being superseded by rings, but it is our conviction that the mule will always be able to produce a superior yarn and will therefore always be required for high-quality goods. The extension of ring spinning only places us deeper in the low-quality market in which fierce foreign competition will continue to operate and probably increase.

We also hold the view that if oils from 1900 onwards had not been cheaper than the installation of efficient non-splash spindle bearings, it is doubtful whether we should have had the incidence of cancer we have experienced.

Our road, therefore, for many years has been clear and we shall continue along that road :—

(1) a non-carcinogenic oil;
(2) non-splash bearings;
(3) compulsory medical examinations;
(4) adequate washing facilities.

For a long time we have been much concerned about the physical welfare of our people, and we shall continue to explore every possible avenue until it can be said that the disease has been eradicated. I have been engaged

in this work for a long time, and I hope it will not be long before we can all see some beneficial results from our joint efforts.

Yours truly,

CHARLES SCHOFIELD,

Secretary.

The Amalgamated Association of Operative Cotton Spinners and Twiners.

115 *Newton Street,*

Manchester 1.

July 22, 1950.

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Oilfield Exploration and Exploitation.

Geology.

1760. New well drilled in Gulf of Mexico. Anon. *Petrol. Engr*, May 1950, **22** (5), B-84.—A well 25 miles offshore from St Mary Parish, Louisiana, on test flowed 789 b.d. of 33° oil from Miocene sand at approx 11,650 ft. Pay porosity varied up to 26%. C. A. F.

1761. Extends Warren field. Anon. *Petrol. Engr*, May 1950, **22** (5), B-82.—A well drilled in Lea County, New Mexico, which produced 840 b.d. from 9110–9176 ft with G.O.R. 539 : 1, has extended the Warren field ½ mile to the northwest. C. A. F.

1762. Gulf well flows 1252 bbl in 24 hr. Anon. *Petrol Engr*, May 1950, **22** (5), B-82.—4 Foster in Okfuskee County, Oklahoma, had an initial potential of 1252 b.d. of water-free oil. Total depth was 3484 ft. C. A. F.

1763. Gas sector gets extension. Anon. *Petrol. Engr*, May 1950, **22** (5), B-82.—1 Slater, 1 mile south of the Woodlawn field in Harrison County, Texas, flowed 4,390,000 cu. ft. gas and 192 b.d. of 62·9° distillate from the Pettit from 6487 to 6497 ft and 6502 to 6508 ft. C. A. F.

1764. Cities Service completes Scurry County wells. Anon. *Petrol. Engr*, May 1950, **22** (5), B-82.—Three wells recently completed in Scurry County, Texas, had the following production characteristics :

In the Kelly field, Andress 3 flowed 1144 b.d. and Austin 3 1231 b.d. In the Diamond M field, Johnson H 5 flowed 1203 b.d. C. A. F.

1765. Drills 3rd Tucupido well. Anon. *Petrol. Engr*, May 1950, **22** (5), B-80.—A third well in the Tucupido area, Venezuela, had an initial potential of 1025 b.d. from the Chaguaramas from 3000 ft. Total production of the Tucupido area is approx 9200 b.d. C. A. F.

Drilling.

1766. Economics of contract drilling in California. R. A. Powell. *Oil Gas J.*, 8.6.50, **49** (5), 50; *Petrol. Engr*, June 1950, **22** (6), B-64.—An examination of the factors affecting contract drilling indicates that all costs have risen in the last three years, labour, rig supplies, transport, depreciation, supervision, and overheads. As a result there is an increase in operating costs of 18%. It is estimated that 72% of all drilling costs are chargeable to time, and by improved practices, equipment, etc., footage costs have been reduced.

The advantages to the operator of contract drilling, are described, and the necessity for contract drillers to maintain a high degree of efficiency is emphasized. C. G. W.

1767. How to repair wells damaged by earthquakes. Anon. *Petrol. Engr*, May 1950, **22** (5), B-47.—Severe bending of pipe in earthquakes is usually remedied by cementing off the lower zone and whipstocking and re-drilling below the offset section. A new method developed involves removing pipe down to the offset and reaming the hole to 30 in dia. The kinked section is washed over and a cutter run in on a flexible pipe. This is run below the bent section and a cut made. The well bore is conditioned to a point below the top of the lower section casing before it is contracted and re-connected with a reconditioned upper section. C. G. W.

1768. Mobile exploration rig for offshore work. J. R. Pemberton and H. A. Hansen. *Oil Gas J.*, 18.5.50, **49** (2), 122.—A mobile offshore drilling unit has been designed which it is claimed can drill to 15,000 ft in 350 ft of water. If successful it is claimed that the rig will save 60% of present exploration costs in the Gulf of Mexico. The proposed rig consists of (*a*) a triangular submersible pontoon of side 250 ft with hinged stabilizing arms extending from the middle of each side. The stabilizing arms contain floodable compartments.

(*b*) A buoyant triangular platform carrying all drilling equipment, barge controls, living quarters, etc.

(*c*) Supporting towers each 450 ft high placed at the corners of the pontoon.

The drilling platform is suspended from the tops of the towers by crown and travelling blocks and is raised to about 30 ft above water level during drilling.

It is planned to use a 1600-h.p. diesel electric standard power rig with a 16 by 26 by 136 ft double bulge derrick capacity 800,000 lb.

The rig can be levelled by synchronized hydraulic jacks at the foot of each tower and permits drilling with ocean floor inclination of 10°. C. G. W.

1769. New type derrick foundation in Lake Maracaibo. W. A. Jansen and A. Kranendonk. *Ingenieur*, 23.6.50, **62** (25), M-41.—The system employed involves the use of prefabricated structure which rests on the lake bottom and receives additional support from temporary piles which have previously been driven at the point where the derrick is to be situated. The structure is fabricated from steel, which material was chosen for its financial and economic advantages in spite of the corrosive nature of the water of the lake. The piles which will eventually carry the weight of the derrick are driven through the hollow tubes of which the afore-mentioned structure is built up.

The system has the advantages that the execution of pile-driving is so precise that a prefabricated platform can be fitted without trouble, and that the fitting of submarine bracings is avoided. Furthermore, the circular space between the hollow tubes and the bearing piles can be grouted, thus providing some degree of corrosion protection.

By way of illustration a considerable number of drawings of the structure and photographs of its installation are appended. R. R.

1770. Automatic weight control. R. F. Carlson. *Oil Gas J.*, 27.4.50, **48** (51), 170.—A new type of regulator for the Brantby hydraulic feed unit for automatic drilling weight

control, is described. This regulator supplements the manually set needle valve manifold, with a motor valve controlled from the dead line. The motor valve is closed by a spring above a diaphragm and opened by air pressure beneath the diaphragm. Air feed to the diaphragm is controlled by a flapper-type valve operated from the dead-line diaphragm. Rate of feed-off is set by adjustment of the flapper valve. C. G. W.

1771. Diamond drilling operations. J. J. Sanna. *Oil Gas J.*, 18.5.50, **49** (2), 129.—Important factors in successful diamond drilling are: (1) uniform feed as bit cuts formation; (2) high fluid circulation to remove cuttings; (3) avoidance of debris in bottom of the hole.

Suitable operating practices for various conditions are presented graphically, and recommended drilling practices are described. C. G. W.

1772. Freezing plugs in high pressure wells. I. A. Miller. *Oil Gas J.*, 30.3.50, **48** (47), 95.—The technique of using dry ice to freeze a plug in a drill pipe has been developed since 1946. It is emphasized that the method is not routine operation but is used only when other methods of control are impracticable or unsafe.

Case where the dry-ice method has successfully been used are described. C. G. W.

1773. Use of tubing as drill pipe. W. F. Bates. *Oil Gas J.*, 1.6.50, **49** (4), 54.—Theoretical and practical considerations favour the use of $6\frac{3}{4}$-in hole using $3\frac{1}{2}$-in drill tubes for show-hole drilling. A portable drilling unit was available which, using $3\frac{1}{2}$-in 9·3-lb tubing, could be used to a depth of 6500 ft. Drilling tests have been carried out in a number of regions and performances and costs analysed. Only rough comparisons with conventional drilling methods are attempted. C. G. W.

1774. Significance of pumping rates in squeeze cementing. G. C. Howard and C. R. Fast. *Oil Gas J.*, 25.5.50, **49** (3), 120.—See Abstract No. 429. C. G. W.

1775. Pumpability, rheological properties and viscometry of drilling fluids. H. van Olphen. *J. Inst. Petrol.*, 1950, **36**, 223–34.—From an analysis of mud flow through the rotary mud circuit the rheological information required for the prediction of pressure losses in the various parts of the circuit is formulated. The development of a suitable viscometer is described, and some results are presented. A. R. W. B.

1776. Evaluating native clays for use as drilling muds. V. B. Zacher. *Petrol. Engr*, Apr. 1950, **22** (4), B-50.—Two formulæ have been developed for evaluating clays for use as drilling muds. One applies to colloidal clays or gels and the other to average or heavyweight drilling muds. The result is expressed as a "merit index." The formulæ are: (*a*) for colloidal clays

$$\text{Index} = \frac{1000\,Y}{L.T.R.}$$

where Y = yield, brl of mud/ton of dry clay for 30 sec visc.
L = water loss (cc) at 30 sec vis and 185° F.
T = cake thickness (mm) at 30 sec visc and 185° F.
R = Reaction to tetra sodium pyrophoshate from 30 sec visc at 1 lb/brl or 1·7 g per 600 cc.

(*b*) For average or heavy muds

$$\text{Index} = \frac{1000\,W}{L.T.R.}$$

W = mud weight lb/ft³ at 30 sec visc.
L = water loss (cc) at 78 lb/ft³, 185° F.
T = Cake thickness (mm) at 78 lb/ft³ and 185° F.
R = reaction to tetra sodium pyrophosphate from 30 sec visc at 1 lb/brl or 1·7 g per 600 cc.

Viscosities are read at 500 cc in 500 cc cut using a $\frac{3}{16}$-in orifice. All filter tests taken at 100 p.s.i. from zero to 15 min using a 3-in-dia cell. C. G. W.

1777. Pipe racks and mud ditches redesigned to increase efficiency of drilling rig. Anon. *Oil Gas J.*, 11.5.50, **49** (1), 91.—Pipe racks constructed of flat panels made of drill pipe with a box-type walkway save much time when erecting and dismantling and simplify handling.

An all-steel mud system with twin flumes gives an adaptable, portable unit. Flumes can be closed by inspection-type gates and also are equipped with dump gates for disposing of accumulated cuttings, etc. C. G. W.

1778. Steam rig runs 90-day test on water-tube boilers. L. S. McCaslin. *Oil Gas J.*, 13.4.50, **48** (49), 84.—A field test has been completed on a 300-h.p. coil-type water-tube boiler designed for oilfield use. A vertical-type steam-engine is under development for use with this boiler. It is anticipated that the combination will prove equally as portable as a power rig. The field test is described. C. G. W.

1779. Obtaining porosities from radioactivity logs. R. E. Bush. *Oil Gas J.*, 27.4.50, **48** (51), 153.—A method is described whereby a radioactivity log may be used for determining porosities within a field or area. A cored well which has been logged by radioactivity methods is used as a base well from which a neutron-derived porosity curve and a gamma-ray subtractive curve may be determined. These curves are then applied to uncored or unknown wells with the same bore and the same casing programme. The examples discussed are based on quantitative interpretations of radioactivity logs of wells in Scurry County, Texas. References are appended. C. G. W.

1780. Basis for selecting alloy cast irons for petroleum industry. F. G. Sefing. *Refiner*, 1950, **29** (1), 97–101.—The range of properties available in cast irons has been widened in the last thirty years. Typical alloys for abrasion resistance, high-temperature resistance, etc., are given. Tables are given showing the properties of the various cast irons.

A discussion by T. E. Eagan follows. R. W. G.

1781. Patents. A. J. F. Siegert and B. E. Watt, assrs to Texaco Development Corpn. U.S.P. 2,504,888, 18.4.50. The method of logging a borehole by passing through the hole a source of gamma-rays capable of penetrating subsurface formations to induce neutrons therefrom, and measuring variations in the intensity of the neutrons reaching the hole as the source and neutron detector are moved through the hole.

G. Herzog, assr to Texaco Development Corpn. U.S.P. 2,506,149, 2.5.50. Well-logging involving the detection of variations in radiation along a borehole is improved by passing a chain of spaced radiation detectors along the borehole so that the responses of individual detectors to radiation from the same level in the borehole are displaced in time, and automatically combining the individual responses from that level by automatically accumulating near the surface of the ground the responses as a series of condenser charges. C. F. S.

Production.

1782. Research on shooting oil and gas wells. B. F. Grant, W. I. Duvall, L. Obert, R. L. Rough, and T. C. Atchison. *Oil Gas J.*, 1.6.50, **49** (4), 65.—A series of four shooting tests have been made to determine the instruments best suited for field experimentation and to develop testing procedures: (*a*) to compare effects on rock of varying types of explosive, methods of loading stemming, etc., (*b*) to correlate the characteristics of the strain wave produced by an explosive shot with the change in fluid conductivity of the shot hole.

The technique employed resistance strain gauges bonded to a piece of core which is oriented and cemented in a diamond drill hole. The gauge is connected through a preamplifier to an oscilloscope.

Series of test were run (*a*) to determine effect of explosives and controllable shooting procedures, (*b*) to determine the breaking characteristics of the sandstone used, (*c*) to compare different types of instrument, (*d*) to develop a technique for instrumenting water-injection tests so that the intensity of the shot can be correlated with changes in fluid conductivity produced by the shot.

Data obtained in each series of tests are tabulated and plotted. References are appended. C. G. W.

1783. Application of build-up curves to determine reservoir pressures and permeabilities. C. C. Miller, A. B. Dyes, and C. A. Hutchinson. *Petrol. Engr*, June 1950, **22** (6), B-7.—A method for obtaining effective permeability and reservoir pressure from pressure build-up curves is presented. When build-up data for a well are plotted as pressure *vs* log time there will be a section of the curve that is almost straight. The slope of this portion of the curve is related to the effective permeability in the drainage area by the equation

$$k_2 = \frac{162{\cdot}5\, q.\mu.F}{m.h.}$$

where k_2 = effective permeability to oil in drainage area, millidarcys;
m = slope of straight-line portion of curve;
q = oil-production rate prior to shut-in stock tank, b.d.;
F = formation volume factor reservoir brl per stock tank, brl;
h = net effective pay thickness, ft;

An equation is given which provides a check on to whether the correct portion of the curve has been used.

The analysis breaks down when the well is unstabilized at the time of shutdown and also when the well is in a gas-cap region. A specimen calculation is made.

The check equation is

$$T = \frac{0{\cdot}0002637\, k_2 t}{f\beta\mu r_e^2}\left[\frac{Y_0 + Y_G R}{F Y_T}\right]$$

where T = dimensionless variable lying in the range 10^{-2}–10^{-1};
t = time after shut-in, hr;
k_2 = effective permeability to oil, millidarcys;
f = formation porosity, fraction;
β = mean fluid compressibility, p.s.i.$^{-1}$;
r_e = radius of drainage, ft;
Y_0 = density stock tank oil, lb/stock tank brl;
Y_G = density of gas, lb/standard cu. ft.;
Y_T = mean density of reservoir fluids, lb/reservoir brl;
R = gas oil ratio standard cu. ft/stock tank brl;
F = formation volume factor.

Reservoir pressure may be estimated by the equation.

$$P_e = P_x - m\log(10T_x) + 0{\cdot}6205\, m\frac{q_e}{q_w}$$

where P_e = reservoir pressure, p.s.i.;
P_x = pressure point at the end of the straight section of the semilog build-up curve;
m = slope of straight-line section of the semilog build-up curve;
T_x = dimensionless variable from previous equation at $t = t_x$ corresponding to P_x;
$\frac{q_e}{q_w}$ = relative degree of migration over external boundary influx rate/production rate fractions.

A sample calculation is performed assuming $\frac{q_e}{q_w}$ = zero.

Equations are also derived for estimating the approximate times required for attaining steady state conditions and the shut-in period. The ratio of the permeabilities determined by the productivity index method and by the pressure build-up methods

gives an indication of any damage or reduced permeability in the vicinity of the well, and of the degree of improvement that might result from treatment.

Equations are presented for estimating damage and potential productive capacity and a sample calculation performed. References are appended. C. G. W.

1784. Subsurface pressure–temperature–flow conditions recorded on a single run D. H. Stormont. *Oil Gas J.*, 13.4.50, **48** (49), 80.—A unitized instrument for surveying pressure–temp–flow conditions has been developed. The instrument can be lubricated through 2-in o.d. tubing, and a collapsible expandable packer which can be expanded to 7-in dia so that dependable flow conditions may be obtained. Readings taken at each level are telemetered to the surface and recorded. Accuracies claimed are 1 lb in 6000 p.s.i. and $\frac{1}{30}$ of 1° F. Pressure, temp, and flow changes vary the frequency output signal of the sensing elements, and changes of frequency of 1 in ten thousand may be determined. The instrument is 1½ in in dia by 9½ ft long and has successfully been lubricated into wells with surface pressures of 2500 p.s.i. C. G. W.

1785. Oil recovery by high pressure gas injection. L. P. Whorton and W. L. Kieschnick, Jr. *Oil Gas J.*, 6.4.50, **48** (48), 78; *Petrol. Engr*, Apr. 1950, **22** (4), B-84.—The value of early injection of gas into reservoirs to maintain reservoir pressures has long been established. It is argued that injection of gas at pressures considerably higher than those now in use will result in changes in properties of virgin oil and injected gas and will give higher recoveries.

A study of a number of condensate systems indicated that the addition of ethane, propane, or butane to a heavy hydrocarbon system results in a large increase in the equilibrium constant k of the hexane plus material. Applying this argument to oil reservoirs, if a system containing an appreciable concentration of ethane, propane, and butane were injected into a reservoir at high pressure, retrograde evaporation of part of the oil phase might be expected. The greater the pressure the higher the concentration of heavy constituents in the vapour phase. A calculation indicated that a rich injection gas could evaporate 45% of pentane and heavier fractions of the crude.

Static experiments were performed to demonstrate the evaporation effect predicted. A lean gas and a rich gas were contacted with a reservoir oil at 4000 p.s.i. and the resulting vapour analysed. A considerable fraction of reservoir oil was found to be evaporated. These experiments showed that injection gas enriched by a first contact with reservoir oil will dissolve in reservoir oil, giving a highly expanded system. Hence after a first-stage recovery by injecting rich gas, the expanded residual oil can be recovered by further gas injection.

To study the process under flowing conditions dynamic experiments were performed. A 25-ft steel jacket was packed with sand. High-pressure and atmospheric visual separators permit observation of effluent. The system was designed for use at pressures up to 5000 p.s.i. Experiments were carried out to determine recoveries after virgin reservoir oil production gas breakthrough point and ultimate recovery, for a series of injection gases at a series of pressures.

Using lean gas ultimate recovery at 2780 p.s.i. was 43% and 4000 p.s.i. was 70%. Using a rich gas a recovery of 80% at 4000 p.s.i. was obtained. Experimental methods are described, and results are tabulated and plotted.

The advantages of the method over the conventional gas-injection methods are due to: (1) Retrograde solubility effects causing enrichment of gas. (2) Solution of enriched gas in oil causing swelling of oil. (3) Reduced visc of liq phase and increased visc of vapour phase increasing displacement efficiency. Channelling has adverse effects on the operation, and the presence of intermediate hydrocarbons (C_2-C_7) in the reservoir oil are essential. References are appended. C. G. W.

1786. Material balance calculation on North Snyder field Canyon Reef reservoir. Anon. *Oil Gas J.*, 11.5.50, **49** (1), 85.—Material balance calculations have been made to determine the theoretical reservoir performance.

The equation for a solution gas drive reservoir with no original gas cap is:

$$L = \frac{Q[\gamma\beta + R - S]}{Si - S - \gamma(\beta_1 - \beta)}$$

where L = original oil in place as brl of residual oil;
S = gas solubility by differential liberation standard cu. ft. per brl residual oil;
γ = volume factor for gas standard cu. ft. per reservoir brl;
β = formation volume factor of reservoir oil by differential liberation, reservoir barrels per brl of residual oil;
Q = cumulative production, brl of residual oil;
R = cumulative produced gas/oil ratio standard cu. ft. per brl of residual oil;
i refers to initial conditions.

Calculations are confined to regions where the gas saturation is less than 10% and where the effective permeability to gas is zero. The factor R in the above equation is merely the solution ratio, and is given by:

$$R = \frac{Q'R' + \Delta Q(r)}{Q' + \Delta Q}$$

where ΔQ = production between two pressure points, brl of residual oil;
r = average gas/oil ratio between two pressure points. Standard cu. ft/brl residual oil

Q' and R' refer to preceding pressure point. Assuming $L = 1$ so that Q and ΔQ are expressed as fractions of original oil. Equation 2 is substituted in Equation 1, and the resulting equation solved for various pressure points. Results are tabulated and plotted and a pressure-decline curve established. C. G. W.

1787. A rapid method for permeability calculations. A. S. McLatchie. *Petrol. Engr*, Apr. 1950, **22** (4), B-72.—The construction and use of a nomograph for rapid determination of permeabilities of core from available laboratory data are described. C. G. W.

1788. Subsurface oil well flow meter. M. Stephenson. *Oil Gas J.*, 11.5.50, **49** (1), 96.—To determine the position and importance of zones of fluid entry into wells an impeller-type subsurface flow meter has been developed. The trial model has max dia of 1⅜ in and is 3 ft long. The instrument consists of three sections plus centralizer springs. The impeller and impeller shaft, rotated by part of the well production, are housed in the lowest unit. Above this is a transmission and gear-reduction unit. By means of a magnetic coupling the rotation of the propeller shaft is transmitted through a stainless-steel wall into the pressure-tight part of the meter. The speed is then reduced in the ratio 3,600 : 1. The recording unit completes the pressure-tight section of the instrument. The stylus is coupled directly to the transmission unit. The chart traverse is directly geared to the stylus shaft. Time intervals are recorded by jerking the instrument by braking at each desired time interval. The recording unit may be replaced by the timing and recording unit of an Amerada subsurface pressure gauge. The instrument may be calibrated with water. Range of the instrument is from 10 cm to 2–3 m per sec, and it has been used at pressures of 4000 p.s.i. and temp of 180° F. Operating experience with the instrument is described A survey on a 7000-ft well has been completed in 190 min, and the speed, simplicity, ease of maintenance, and rapidity of the operation are the major advantages. Modifications to extend the application of the method are described. C. G. W.

1789. Pumping deep wells. H. E. Allen, F. M. Beal, and R. C. Curtis. *Oil Gas J.*, 18.5.50, **49** (2), 134.—A study is made of present deep-pumping practices. It is shown that for sucker-rod pumps improvements in both surface units and in sucker rod performance must be obtained if economic pumping depths are to be increased.

A comparison of beam and hydraulic surface units for sucker-rod pumping indicates that for a production of 100 b.d. the limiting depths are 15,000 ft for hydraulic units and 12,500 ft for beam units. Subsurface hydraulic units are also limited to 12,500 ft. The experience of one operator pumping from 10,600 ft with sucker-rod pumps and a subsurface hydraulic pump, is described. Full operating details are given, but owing to the short time and experimental nature of the operation no conclusions are drawn.

References are appended. C. G. W.

1790. Practical aspects of multiple pack-shots for bottle-necked wells. F. R. Cozzens. *Petrol. Engr*, May 1950, **22** (5), B-54.—Small dia of wells in the producing zone may prohibit use of sufficiently large explosive charges for efficient shooting. Tight sand sections may require 6–8 qt/ft, whereas the max charge in a 5-in-dia bore is 3–4 qt/ft. A method of obtaining efficient fracturing is the multiple pack-shot method. In the case of a new well the well is drilled and logged to the bottom of the producing zone. The bore is then backfilled to the bottom of the topmost tight section. This section is then squib shot by packing with solidified nitroglycerine treated with oil. The explosive is placed by a dump shell. If large cavities are required two or more squib shots may be used. The well is then drilled to the next tight section and squib shooting repeated. This continues to the base of the pay zone. The oil sand is then cleaned, and the main charge of explosive loaded. The bulk of the charge is carried in the enlarged section opposite tight zones. The charge is best detonated electrically, stemming or tamping is used if desired.

When redrilling old fields tight sections may be squib shot as they are drilled. Reshooting old wells is more difficult. If the well is calipered it may be possible to set bridges at desired points, or it may be necessary to plug the hole back. An alternative method is to use drillable pipe as a bridge support.

A clean out with strong salt water is recommended. In some cases, a weak acid wash or paraffin solvent wash may be desirable. These should be followed by water wash. C. G. W.

1791. Bituminous sands. *Ann. Rep. Res. Council Alberta*, 1949, **8**.—Operations during 1949 at the Bitumont experimental separation plant, Alberta, are described. The plant is used to separate bitumen from bituminous sands quarried in the neighbourhood.

Trial operation of the plant started late in 1948. After a number of operational difficulties, new equipment installed early in 1949 functioned well. It is considered that the separation of sand from oil was more complete than that obtained by any former plant.

Data on plant performance are given: Bituminous sand fed through the plant contained approx 12% oil by weight. Throughput was approx 500 tons/day with 90% recovery of oil as wet crude. Water content of crude varied from 25 to 45%. A dehydration unit removed the water and reduced mineral content to less than 3%. Approx 6% of the oil was lost in dehydration by emulsion formation.

Total porosity of the sand is 33–35%. Water saturation varies from 3·5 to 14·5%, and oil saturation from 72 to 86%. C. A. F.

Oilfield Development.

1792. Exploratory drilling in 1949. F. H. Lahee. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 995–1013.—This is the fifth annual report on data gathered by the A.A.P.G. Committee on statistics of exploratory drilling.

During 1949, 9058 exploratory holes were drilled in the U.S. The total exploratory footage was 34,798,291 ft or 3842 ft per hole. These figures compare with 32,741,097 ft drilled in 8013 exploratory holes, with an average depth of 4086 ft in 1948.

Some data on Canada and Mexico are also presented. E. N. T.

1793. Developments in Arkansas and north Louisiana in 1949. M. W. Corbin. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1199–211.—Wells drilled during 1949 in Arkansas and north Louisiana totalled 1804—seven less than in 1948, when 1811 wells were drilled.

There were 193 wildcats drilled in 1949; of this total, eighty-one were drilled in Arkansas and 112 in north Louisiana. There were 203 producers completed in Arkansas and 1120 in north Louisiana.

In Arkansas seven new fields were discovered. Of these, four were new oilfields, two were new gas fields, and one was a distillate field. In north Louisiana, eight new oilfields, one new gas field, and two new distillate fields were discovered.

During the year, 29,776,615 brl of oil were produced in Arkansas, and 51,493,820 brl of oil in north Louisiana. E. N. T.

1794. Developments in Arizona, western New Mexico, and northern New Mexico in 1949. P. H. Umbach. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1144–9. Forty-three wells

were drilled in 1949 in western and northwestern New Mexico compared with fifty-four wells in 1948. Eleven wildcat wells were drilled, two of which were commercially productive.

Four wildcat wells were drilled in 1949 in Arizona, compared with three wells in 1948. None was commercially productive. E. N. T.

1795. Developments in Atlantic coastal states between New Jersey and North Carolina in 1949. H. G. Richards. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1224–5.—There was practically no oil activity in the Atlantic coastal plain during 1949. Maryland had a successful gas well in Garrett County. Oil and gas were obtained in various parts of western Virginia, but there were also a number of dry holes in that area.

E. N. T.

1796. Developments in Illinois and Indiana in 1949. A. H. Bell and R. E. Esarey. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1078–89.—A total of 4018 wells were drilled for oil and gas in Illinois and Indiana in 1949 as compared with 3663 in 1948, an increase of 10%. Total oil production increased 3%, from 71,782,000 brl in 1948 to 74,139,000 brl in 1949.

Most of the discoveries in 1949 were in Mississippian formations, but the Devonian limestone produced oil in six new pools, Pennsylvanian sandstone in five, Ordovician limestone in three, and Silurian limestone in one. E. N. T.

1797. Developments in north Mid-continent in 1949. J. R. Berg. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1097–105.—Some eighty-nine new fields (and pools) were discovered in Kansas during 1949, including eighty-five oil discoveries, and four gas discoveries. In addition, there were five discoveries of deeper production in previously existent pools, including one gas and four oil discoveries.

There were no important developments in Iowa, a few unsuccessful tests in Missouri, and three new discoveries in Nebraska.

Kansas produced a total of 102,873,779 brl of oil and casinghead gasoline, and 263,225,963 M.c.f. of gas during 1949. E. N. T.

1798. Oil and gas developments in Kentucky in 1949. E. B. Wood. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1066–72.—The ratio of successful wells to dry holes in Kentucky was much greater in 1949 than in 1948, but only eastern Kentucky showed an increase in oil production, which totalled 8,853,311 brl for the entire state. Most of the gas development took place in the Big Sandy gas field of eastern Kentucky.

A record number of "deep" wells were drilled, and a large number of them were successful oil or gas wells in the St Peter and Know zones. E. N. T.

1799. Developments in Louisiana Gulf Coast in 1949. G. N. May. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1191–8.—In 1949, 956 wells were drilled in the Louisiana Gulf Coast. Of this number, 261, or 27·3%, were classified as exploratory wells and 695, or 72·7%, as field-development wells. The number of exploratory wells more than doubled those in 1948.

Of the 261 exploratory wells, 93, or 35·2%, were successful, and of the 695 development wells 528, or 76%, were successful.

The thirty-five new-field discoveries include eighteen oilfields, eleven condensate fields, and six gas fields. Of this number, thirteen were completed offshore.

Total oil and condensate production for 1949 was 145,802,754 brl, an increase of under 2%. E. N. T.

1800. Developments in Michigan in 1949. R. H. Wolcott. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1090–6.—Drilling activity in Michigan during 1949, with a total of 999 wells, showed an increase of 8·9% over the 1948 totals. Total footage drilled was 2,208,527 ft, a 4% increase.

There were no deep tests of any particular significance.

There was some decline in oil and gas production, but, for the most part, due to factors other than abnormal depletion. The oil production was 16,503,473 brl, and the gas production was 246,940,524 M.c.f. E. N. T.

1801. Developments in New York in 1949. E. R. McAuslan. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1043–7.—In the Oriskany sand area there were sixteen wells completed or drilling at the end of 1949, compared with twenty in 1948. There were no new discoveries. Total Oriskany gas production was 1,425,000 M.c.f. In the oilfields there were 860 wells drilled, compared with 1742 in 1948. Total oil production for the year was 4,398,000 brl. E. N. T.

1802. Developments in Ohio in 1949. R. L. Alkire and W. N. Tipka. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1058–62.—A total of 1052 exploratory wells were drilled in Ohio during 1949. This is 470 less than those drilled in 1948. Five new fields were discovered, and four notable extensions were made to existing pools. E. N. T.

1803. Developments in Oklahoma in 1949. J. F. Hardwick. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1106–22.—Few important new fields were discovered in Oklahoma during 1949, although both exploratory and development wells increased in number over 1948. Substantial reserves were added by outpost and discovery wells on the northwest and southwest flanks and the southeastern embayment of the Anadarko basin, the Ardmore basin, and east central Oklahoma.

Production of oil totalled 150,779,000 brl, representing a decrease of 3·08% from 1948. Reserves of oil increased by 6·35%, and total reserves of natural gas also showed an increase.

In 1949, Oklahoma drilled 4308 holes, of which 825 were wildcats, resulting in 169 new discoveries or a 20·48% success ratio. E. N. T.

1804. Developments in Pennsylvania in 1949. C. R. Fettke. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1048–57.—Shallow exploratory drilling in western Pennsylvania (Upper Devonian or higher) during 1949 led to the discovery of three new gas fields only. The total number of shallow wells drilled was 17% less than in 1948. In the Pennsylvania part of the Bradford oilfield, which continued to be the most active area, 1100 new wells were completed, as compared with 2070 in 1948. About half of these were water-intake wells. The Bradford field accounted for 79% of the total oil production in Pennsylvania during 1949. The average daily oil production in the state in 1949 was 31,347 brl, as compared with 35,206 brl in 1948.

Twenty-seven new wells were completed to the deeper formations (Onondaga or deeper) as compared with thirty in 1948. Of these, sixteen were gas wells. The W. R. Barton Estate well No. 8 in the South Summit field of Fayette County, drilled to the depth of 10,312 ft, is now the deepest in Pennsylvania and the Appalachian province, and is the deepest well in the world to be drilled entirely with cable tools.
E. N. T.

1805. Developments in Rocky Mountain region in 1949. C. L. Severy and D. M. E. McLarty. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1032–42.—The exploratory wells drilled in the Rocky Mountain region in 1949 totalled 345, of which fifty-six were commercially successful. In 1948, 277 exploratory tests were drilled, but in that year successes were 10·1% higher than in 1949. Cretaceous objectives provided the greatest number of producers followed by the Permo–Pennsylvania formations. New discoveries at Sussex and Glenrock in the Powder River basin of Wyoming were of significance as they emphasize the trend towards exploration of the flanks and noses of large known structures in search of fault traps. A new Tertiary discovery at Roosevelt in the Uinta basin of Utah has pointed to new objectives which open large areas for exploration.

Development drilling showed a slight decline over the peak of 1948. Geophysical exploration showed a substantial increase in the number of crew weeks of gravity and seismic work done.

In 1949, Utah became a fully-fledged oil-producing state. E. N. T.

1806. Developments in southeastern states in 1949. F. T. Holden. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1212–23.—The states of Alabama, Florida, Georgia, and Mississippi produced in 1949 a total of 40,367,396 brl—a drop of 6,065,033 brl from 1948.

In Alabama fifteen wildcats were drilled and abandoned. Four new producers were added to the Gilbertown field, and oil production amounted to 457,203 brl.

Florida activity declined from the 1948 totals. Nineteen wildcats were drilled and abandoned. Three new producers were added to the Sunniland field, and oil production for the state was 441,820 brl.

Georgia's seven wildcats failed to find oil. Mississippi wildcats in 1949 totalled 117. Seven new fields and four piercement salt domes were found. In the producing fields 159 producers and 56 dry holes were drilled. Production for the state totalled 39,468,373 brl of oil and condensate, a decline of 6,193,740 brl from 1948. E. N. T.

1807. Developments in Upper Gulf Coast of Texas in 1949. J. L. Ballard. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1179–90.—There were 1306 wells drilled in the Upper Gulf Coast districts of Texas in 1949, which is a 15% increase over 1948. Of these, 179 were drilled in search of new structures. This represents a decrease of 16% from 1948, and resulted in the discovery of twenty-eight new fields as compared with twenty-two new discoveries in 1948. These new discoveries consisted of nine oilfields, and fourteen gas-condensate fields.

Considerably more reserves were added by development in old fields. 1127 wells were drilled on known structures, which resulted in the discovery of seventy-three new sands, thirty new reservoirs, and ten important extensions.

Five wildcat wells were completed in the Gulf of Mexico, one of which discovered the State No. 245 gas-condensate field, offshore from Galveston County.

The total oil and condensate production in 1949 amounted to 145,419,014 brl which is a decrease of 42,130,690 brl under 1948. E. N. T.

1808. Developments in east Texas in 1949. D. T. Gibson. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1170–8.—Field well completions in east Texas totalled 924, or 21·4% above the 1948 total. Completed wildcats totalled 188, or 22% above the 1948 total. Nineteen new-field and new-pool discoveries were drilled; fourteen of these were considered successful new-field wildcats; and the remainder of the 188 exploratory tests were dry holes. Although several of the new fields appear to be of moderate size, none appears to be a major discovery. Both fault and basin discoveries were made in 1949.

There was an increase of 63% in drilling in the East Texas field. The 1949 production amounted to 141,241,000 brl, or a decrease of 33,289,000 brl due to tighter proration schedules. E. N. T.

1809. Developments in north and west-central Texas in 1949. J. B. Moorhead and W. O. Ham, Jr. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1150–7.—Production in the north and west-central Texas district in 1949 increased to 68,562,241 brl of oil, and gas production totalled 94,819 M.c.f. There were 4732 wells drilled, of which 1547 wells were exploratory tests resulting in 344 producers, a success ratio of 22%. A total of 138 new fields were discovered.

The seismograph continued as a leading exploration tool, being credited with fifty discoveries. E. N. T.

1810. Developments in south Texas in 1949. B. Scrafford. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1158–69.—In 1949, all phases of development and production in south Texas, except for gas production and the by-products of gas, were below 1948. The 793 wildcat exploratory wells found seventy-two new producing areas, and two of the discovery wells were dually completed. Of the 1848 oilfield-development wells, 1220 were completed as oil producers, 330 as gas wells, and the remainder produced 125,238,744 brl of oil, 44,500,210 brl less than the amount produced during the previous year.

Gas-transmission lines marketed 15,500,000,000 cu. ft. of gas. E. N. T.

1811. Developments in Texas Panhandle in 1949. P. H. Horn. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1123–8.—Drilling activities in the Texas Panhandle continued to increase in 1949. There was a total of 827 wells drilled, of which 91·3% were successful. Production totalled nearly 32,000,000 brl of oil and more than 882,000,000,000 cu. ft. of gas.

There were twenty-six exploratory wells drilled, of which five reached the basement complex. Two of the exploratory wells discovered oil, and two gas. E. N. T.

1812. Developments in west Texas and southeast New Mexico in 1950. J. E. Galley and G. S. Corey. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1129–43.—The number of exploratory tests drilled in this area in 1949 exceeded that of 1948 by 27·5%. Successful new-field wildcats increased by 12·5%, but development drilling decreased. Especially significant was a pronounced increase in proportion of pre-Permian discoveries, together with a decrease in new fields on the Central Basin platform.

The outstanding development of the year was the expansion of reef-limestone production in Scurry County, where existing fields were greatly extended and new fields discovered. New pre-Permian fields in Lea County, an important Ellenburger discovery in Upton County, and a new Permian pay zone were notable.

Total oil production in 1949 was 274,900,433 brl. E. N. T.

1813. Developments in west coast area in 1949. G. B. Moody. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1014–31.—In Nevada no exploratory wells were completed in 1949; in Oregon one new-field wildcat was abandoned and no discoveries were made; and in Washington two new-field wildcats were abandoned and no discoveries made.

In California the total exploratory footage for 588 exploratory wells completed as producers or abandoned as dry holes was 2,138,501 ft. Comparable figures for 1948 were 488 wells and 2,005,366 ft.

The successful wells discovered thirty-one new pools and fields. The Cuyama South field was the outstanding discovery. Production during the year was about 332,942,000 brl of crude oil, 27,189,000 brl of natural-gas liquids, and 543,488,000 M.c.f. of gas (including gas from dry gas fields and residue gas from oilfields). There were forty-six exploratory wells active at the end of 1949. E. N. T.

1814. Developments in west Virginia in 1949. R. C. Tucker. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1063–5.—In 1949, 700 wells were drilled in West Virginia, 25% less than in 1948. Wells completed were: gas, 427; oil, 78; oil and gas, 24; storage, brine, and water-intake wells, 27; dry holes, 144. Oil and gas wells were 8% fewer than in 1948, and the percentage of dry holes to completions increased from 19 to 20 +%. Total footage drilled decreased 614,282 ft under the 1948 total, or 24 + %. The number of wells drilling or unreported if completed at the end of the year was 271, or sixty-two less than in 1948. Preliminary estimates of production for 1949 are: gas, 181,380,000 M.c.f.; oil, 2,830,000 brl. E. N. T.

1815. Developments in Alaska in 1949. R. L. Miller. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1226–34.—Exploration for oil in northern Alaska in 1949 was done under the auspices of the U.S. Navy. Six geological parties and five geophysical parties were in the field during the 1949 season. Geophysical parties made detailed seismic surveys in areas of promise in the Arctic Coastal Plain region and made reconnaissance surveys over more extensive parts of the Coastal Plain. A gravity survey was also made of an area in the northwestern part of the Petroleum Reserve. Four test wells were drilled or being drilled during 1949; two of these reached basement rock at shallow depths on the Barrow high south of Point Barrow, Alaska. South Barrow No. 2 was a successful gas well, and the gas is now being utilized for heating in Camp Barrow.

E. N. T.

1816. Alberta oil for eastern Canada. H. G. Cochrane. *Petrol. Engr*, Oct. 1949, **21** (11), C-11.—In 1947 Canada was only producing from Turner field. Since this date big finds round Edmonton and Lloydminster as well as smaller fields have greatly increased the reserves. Distribution is a problem, since the largest market and refinery capacity is in east Canada. A pipeline from Edmonton to the Lakes has been proposed. At present Vancouver area is supplied from the U.S., the local fields supply the prairies, whilst the big East market is supplied from U.S., Venezuela, and the Middle East. Huge deposits of oil sand at Fort McMurray have largest gas reserves in Alberta. The latter are capped as at present there is no outlet for the products.

G. K. A.

1817. Developments in Canada in 1949. J. G. Gray and W. A. Roliff. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1235–59.—The exploration effort in western Canada was greater than that of 1947 and 1948 combined, and was rewarded with the discovery of important new fields in Alberta.

The total number of wells drilled in western Canada amounted to 845, of which 784 were drilled in Alberta, fifty-eight in Saskatchewan, and three in Manitoba. In Alberta there were 549 development wells drilled and 235 exploratory holes; of the latter, 200 wells were new-field wildcats, of which thirteen were oil discoveries, eighteen were gas discoveries, two were gas condensate wells, and 167 were dry holes.

Developments during 1949 increased the estimated oil reserves of western Canada to approximately 1100,000,000 brl and materially increased the gas reserves of Alberta. Oil production was increased to approx 60,000 b.d.

Exploration and development activities in eastern Canada were on approx the same scale as in 1948.

282 development wells were completed, 280 in Ontario, and two in New Brunswick. Exploratory drilling consisted of eighty-two wells in Ontario, one in Gaspe, and two in New Brunswick. Five small gas pools were discovered in Ontario. E. N. T.

1818. Developments in Mexico in 1949. E. N. Guzman, F. M. Uhink, and S. H. Folk. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 1260–82.—During 1949, 162 new wells were drilled in Mexico, representing an increase of 100% over 1948. Fifty of the total number of wells drilled were exploratory tests, of which fourteen were completed as producers.

Discoveries made during 1949 included one oilfield, two gas and distillate fields, four oil pools, three gas pools, and four extensions.

Crude oil and distillate production during 1949 was 60,896,660 brl, the largest amount produced in any year since 1927. Of the 1949 total production, 95·4% was produced by Petroleos Mexicanos and 4·6% by other operators. E. N. T.

1819. Fifty years' progress in the geological exploration of the Netherlands. F. J. Faber. *Ingenieur*, 19.5.50, **62**, (20) M-23; 26.5.50, **62** (21), M-31.—The paper reviews fifty years' progress in exploring the subsurface and tectonical structure of the Netherlands. Some exploitation of the carboniferous deposits had actually taken place as long ago as the twelfth century, but in spite of this, only two coal-mines were in operation in the south of Limburg at the beginning of the present century, and only a few drillings had been made in the eastern part of the country.

In the early 1900s, investigation of the subsoil was started. Wacholder published in 1901 what proved to be a completely wrong view as to the depth of the carboniferous layer, and much fruitless exploratory work was carried out in consequence. The investigation, which was taken once by Van Waterschoot and eventually completed in 1923, led to the discovery of valuable coal-fields. The text of the paper is supplemented by numerous diagrams to illustrate the progress that has been made, and the hypotheses of various other workers in the field are mentioned in some detail. The author states that large areas had still to be investigated by drilling, the then (1923) state of knowledge with regard to them being yet restricted to conclusions that could be drawn from geophysical data (of which two maps are reproduced).

A great amount of exploration work has been done since 1932 by oil companies, and the development of the oilfield near Schoonebeek is entirely the outcome of this work. It is pointed out that much information on the subsoil is yet in the hands of the petroleum companies and has not been published, although a number of their secrets were seized by Germany during the war, and could therefore no longer be regarded as confidential. Since the war, further information has become available, and that provided by Mulder is of particular value. Of work actually carried out during the war, the paper published by De Sitte—being the final report on the geophysics of South Netherlands—is of considerable importance

The outcome of the work has not been restricted to the development of carboniferous deposits, for considerable deposits of salt have been successfully worked. So far, however, the exploration for lead and zinc ores in South Limburg has not met with favourable results. R. R.

1820. Turkey has 6 producing wells. Anon. *Petrol. Engr*, May 1950, **22** (5), B-82.—Six producing wells have been drilled, and three are drilling at Ramandag in south-western Turkey. 91,000 brl were produced in 1949, of which approx 52,000 brl were refined at Batman.

Drilling has commenced in the Adana field. C. A. F.

1821. Development of the Dukhan field, Qatar. Anon. *Petrol. Engr*, May 1950, **22** (5), B-37.—The Dukhan field is on the Qatar Peninsula, Persian Gulf. The greater part of the peninsula is sand covered, but there are many Eocene outcrops except in the dune area in the southeast. The structure of the area is a broad anticlinorium, and the Dukhan anticline, approx 50 miles by 5 miles, follows its western margin. The anticline was mapped at surface, although dips are very low. Oil is produced from Jurassic (Zekrit) limestone, which is at 5100 ft at the crest of the structure. The discovery well was completed in 1940 for 5000 b.d., and three wells were drilled before operations were suspended in 1942. Operations were resumed in 1947, and nine productive wells have been drilled at the northern end of the structure.

Crude flows from well-head separators to a central multi-stage separator at Khatiyah, and is piped 73 miles to a terminal at Umm Said which has five completed 130,000-brl tanks and five 148,000-brl tanks under construction. Oil is loaded from the terminal through two double 16-in sea-lines. Export commenced in December 1949.

C. A. F.

1822. Japanese production up. Anon. *Petrol. Engr*, May 1950, **22** (5), B-82.—Japanese production in 1949 was approx 4000 b.d. compared with 3000 b.d. in 1948.

C. A. F.

1823. Patents. H. H. Bell, assr to Continental Oil Co. U.S.P. 2,504,377, 18.4.50. Oil well blowout preventer.

T. Sprague, and R. Higgins. U.S.P. 2,504,462, 18.4.50. Apparatus for sealing oil-wells. C. F. S.

Transport and Storage.

1824. Factors governing the design of a modern tanker with special reference to machinery. W. L. Nelson. *Trans. Inst. mar. Engrs*, 1950, **62** (5), 177.—The principal factors governing design are enumerated. These factors are referred to in showing development of a tanker from initial stages to completion, giving the many reasons for the decision with special regard to type of both main and auxiliary machinery. Comparisons are not made between different types of tankers or their methods of propulsion, but it is pointed out that a tanker capable of carrying and handling all grades of petroleum satisfactorily must be capable of producing an abnormal amount of auxiliary steam, and this means that steam propulsion must be considered seriously. Many figures, diagrams, and tables are included. U. N.

1825. R.A.P. encounter unusual problems in laying 165-mile Toulouse–Bordeaux gas-line. J. P. La Croix. *Oil Gas J.*, 8.6.50, **49** (5), 62.—Overall length of the pipeline of Regie Autonome des Pétroles, France is 500 miles, and it transmits about 30,000,000 cu. ft. gas daily, soon to reach 35,000,000 cu. ft. gas daily; from St-Marcet field to Bordeaux.

Seamless pipe of grade A steel was used, tested at 1400 p.s.i. for 15 sec., the pipe was welded, and placed in ditches 3 ft deep, ditches being hand-dug in cities because of underground cables and pipes. Electrolytic corrosion is particularly dangerous in southwest of France, where most of the lines run parallel to electric railways. Pipe was coated with hot coal-tar enamel and wrapped with glass fibre and all welds similarly treated after testing. G. A. C.

1826. Friction co-efficient for circular pipes at turbulent flow. J. R. Finniecome. *Mech. World*, 30.6.50, **127** (3311), 725.—The main purpose of the paper is to examine

the wealth of published data connected with friction drop in pipes and to show the relationship between the various formulæ and test results; to review the essential factors influencing the friction coeff in circular straight pipes, and finally to correlate useful information relating to the pressure drop in smooth, rough, or corrugated pipes. Table I gives a summary of formulæ on friction coeff of smooth pipes, and Table II gives a summary of the values of the friction coeff of smooth pipes based on formulæ of various authors. A. S.

1827. Radiographic weld control for pipe line construction. W. W. Offner. *Pipe Line News*, Mar. 1950, **22** (3), 30.—Weld inspection by radiographic methods is performed by placing a radiation source of X-rays or gamma-rays on one side of the weld and a radiographic film on the other. Changes in the density of the material are recorded as light or dark patches on the film. Insufficient weld penetration and poor fusion—two of the most prevalent defects are readily detected. Typical radiographs illustrating various defects are presented. C. G. W.

1828. Economics of reducing crude oil vaporization losses. R. L. Huntingdon. *Oil Gas J.*, 15.6.50, **49** (6), 108.—Results of weathering tests in open 1000-ml glass cyls on seven Oklahoma and Texas crude oils are given. It is shown that volumetric shrinkage runs much higher for every degree lost by the lower-gravity crude oils such as those in areas where emulsion treating has to be resorted to.

Use of heat-transfer equipment to lower temp of warm treated oil on way to atmospheric storage is discussed.

Seven figures illustrate the article, and the weathering tests are tabulated. G. A. C.

1829. Breather balloon reduces vapour losses. Anon. *Petrol. Engr*, Nov. 1949, **21** (12), C-39.—A great deal of work has been done to conserve valuable light vapour from tank breathing. The use of a breather balloon, first proposed in 1923, has many advantages: ease of installation, simplicity, negligible maintenance, and reasonable life. Sizes range from 1000 to 25,000 cu. ft., the balloon being made of impregnated fabric, the material of construction depending on the type of vapour controlled. Cotton, nylon, and fibre-glass are used for fabrics, and natural or any type of synthetic rubber for the impregnant. A 18,000-cu. ft. balloon will handle the vapours of two 65,000-brl tanks in summer weather. Typical pay-out calculations are given for two breather-balloon installations. G. K. A.

1830. Pumping viscous materials. W. E. Worcester. *Refiner*, 1950, **29** (2), 115–21.—Article is based on a paper presented before the first Pan American Engineering Congress at Rio de Janeiro in July 1949. To-day, almost any material can be pumped if it will squeeze to a film under pressure. Most of the difficulties are encountered before the liq reaches the pump. As the inlet pressure is decreased small amounts of entrained or soluble gases seriously decrease the liq displacement of the pump. Data on friction losses in the pump itself due to visc are now known, and as a result it is preferable to use a large pump operating at low speeds. Due to rapid changes in visc with change in temp, it is important to use data applicable to working conditions. For highly viscous materials the flow will usually be laminar. Accurate visc for a material can often be obtained from pressure drop in pipe where the material is already being moved.

A convenient chart is provided for converting visc readings to absolute viscosities in poises. R. W. G.

1831. Bending moments and leakage at flanged joints. Part I. R. G. Blick. *Refiner*, 1950, **29** (2), 101–3.—The criteria for leakage at a flanged joint due to the effect of bending moment is discussed.

If $\frac{\pi M}{2g}$ exceeds $\frac{H_G - H_{GP}}{2}$, then a gasket will certainly leak. This is a max possible value however, so it cannot be stated that lower values of $\frac{\pi M}{2G}$ will not leak. In some cases it will be found that the value of the critical bending moment (M) is relatively

low, so that it is wise to try and locate the flanges in suitable positions to lower this moment.

G = mean gasket dia;
H_{GP} = total gasket load required to hold pressure without leakage;
= $2b\,\pi\,Gmp$;
$2b$ = effective operating width of gasket;
m = gasket coeff;
p = internal hydraulic pressure (p.s.i.). R. W. G.

1832. Pressure vessel considerations—flanged and dished heads. H. E. Lonngren. *Refiner*, 1950, **29** (2), 147–9.—Equal strength of a shell and a dished head is contained in the expression $\frac{2SE_st_s}{D_m} = \frac{2SE_ht_h}{R_cW}$

where S = allowable stress;
t_s = shell thickness;
R_c = mean crown radius;
D_m = mean crown diameter;
E_s and E_h = efficiency of welded seams;
t_h = head thickness;
W = a factor.

Difficulty is experienced in designing to this formula, since the A.P.I.–A.S.M.E. code formula for t_h contains the factors R_c and W, which in turn are functions of t_h.

A graph is presented which assists in solving this expression. R. W. G.

1833. Minimum thickness of cylindrical vessels. R. R. Maccary and R. F. Fey. *Refiner*, July 1949, **28** (7), 136–8.—In the design of a cylindrical shell, the thicknesses obtained by the use of stress equations are considered to be too thin because of manufacturing difficulties and rigidity of the cylindrical form. Charts are presented giving recommended min thicknesses for the following cases: (1) min thickness against shell dia; (2) bottom course—cylindrical storage tank; (3) limiting stresses due to wind resistance of vertical vessel; (4) limiting deflection due to wind resistance; (5) cylindrical vertical vessel subject to axial compression. W. E. M.

Refinery Operations.

Refineries and Auxiliary Refinery Plant.

1834. South Fullerton gasoline plant. Good example of conservation and producer cooperation. J. M. Hillsman and E. W. Kilgren. *Oil Gas J.*, 15.6.50, **49** (6), 112.—The gas compression, H_2S removal, dehydration, absorption, and distillation facilities at the plant situated at Andrews County, Texas, and owned by Stanolind Oil Co., processing 38 million cu. ft. gas/day are described. Tables show gas composition and tower schedule, and two flow diagrams are also given. G. A. C.

1835. Redesigning Shell's Heysham refinery. V. S. Swaminathan. *Oil Gas J.*, 29.6.50, **49** (8), 71.—The re-vamping of the wartime refinery at Heysham to process the paraffinic–asphaltic mixed-base Kuwait crude to give motor gasoline, gas oil, and fuel oil is described.

Sweetening of the gasoline by caustic soda and sodium hypochlorite is by existing facilities.

iso-Octane plants and the dehydrogenation section were redesigned for catalytic desulphurization, and the O.N. of the product when leaded with 1·5 cc T.E.L/IG is 6–7 Nos. higher than that of the feed under same conditions.

Harbour facilities had to be considerably extended, and now a vessel of 3000 tons capacity can remain loaded at the pontoon at lowest tides.

Total throughput of refinery is 1,500,000 tons per year. G. A. C.

1836. Shell Haven refinery developments. Anon. *Engineer*, 1950, **189**, 657.—Progress on this job is such that first distillation units are expected to be commissioned Nov. 1950. Estimated intake is 6000 tons Kuwait crude per day, providing in addition to S.R. gasoline, gas oil, and fuel, about 1200 tons naphtha for reforming. Cooling-water requirement of 106,000 g.p.m. is drawn from Thames through 8-ft-dia concrete main, and discharges back to Thames via an interceptor and further 8-ft main. Fresh-water requirement for boilers, etc., is 350,000 g.p.d., and this is supplied by local water board. A. C.

1837. Mechanical modernization at Esso Standard's Baton Rouge refinery. C. P. Hoyt. *Oil Gas J.*, 22.6.50, **49** (6), 178.—The mechanization cost $7 million and includes centralized shops and store-house in one air-conditioned building, ample supply of portable, power, and hand tools; a drained and well-lighted road system and personnel facilities. G. A. C.

1838. Southland plants are Mississippi's own. A. A. Spencer. *Petrol. Engr*, Sept. 1949, **21** (10), C-11.—The original plant of the Paluxy Asphalt Co. is designed to process Tinsley crude by a combination of skimming and thermal cracking, the asphalt plant having a battery of crudizing stills to provide flexibility in asphalt production. The light ends are processed to give 270 b.d. of polymer gasoline. The crude has a field gravity of 33–34 A.P.I., the asphalt content of 50 penetration being 15%. Sulphur is 0·79, but all light products are free, the straight-run gasoline has 52 O.N. but good lead response, as have the thermally cracked gasolines. Kerosine is of good quality and of low sulphur content, diesel fuel has low sulphur and a cetane rating of 55–57, but residual fuels have 1% sulphur. Heidelberg crude which is processed in another plant has 49% asphalt of 85 penetration and 4% sulphur. Even so, low products are comparatively sulphur free. G. K. A.

1839. Expansion at Cartagena refinery in Spain. Anon. *Petrol. Engr*, Nov. 1949, **21** (12), C-37.—A 5000-b.p.s.d. refinery is nearing completion near Cartagena. The plant includes three 22,000-lb/hr Spanish Babcock and Wilcox boilers designed to operate at 170 p.s.i. and two 1200-kVa Brown–Boveri condensing electrical generating units. A two-stage distillation unit by Foster Wheeler will provide three lube-oil cuts and the usual gasoline, kerosine, and gas oil cuts. The gasoline will pass through a continuous doctor sweetening process, while the kerosine is treated by an acid-batch process. Persian Gulf crude is handled from a prefabricated concrete wharf, while almost all of the products are shipped by tanker to other parts of Spain. Plans are being drawn up for a thermal reformer and a catalytic polymer plant. G. K. A.

1840. Kansas plant additions improve output. V. R. Oakley. *Petrol. Engr*, Oct. 1949, **21** (11), C-28.—The difficulty encountered by the small refiner in improving quality has been overcome by Bareco Refinery. Initially this consisted of a 7500-b.d. crude-oil pipe still, a Dubbs-type thermal cracking still, and a U.O.P. catalytic polymerization unit. The addition of a Perco desulphurization and reforming unit for treating straight-run gasoline has increased O.N. from 71 on the straight-run to 77·7 research method when operating at 930° F, or to 82·5 when running at 960° F. Normal recovery is 94·9 vol %. The plant runs on a 3·5-day period, so that no caustic wash is required. The further addition is a L.P.G. plant to produce propane and butane according to seasonal demands. The feed stock for this plant consists of Perco fractionator accumulator gas and poly unit effluent. Over one period kerosine production was cut out—the kerosine being run into the Perco reformer—which still produced a 400° E.P. reformed gasoline with no change in reforming conditions. Operating at 960° F. yields of 88·2% of 82·5 O.N. (+ 3 ml T.E.L. per gal) doctor sweet gasoline are produced with a two-day process period. Regeneration is by controlled burning with air and steam. G. K. A.

1841. New refinery specializes in sour crudes. A. L. Foster. *Petrol. Engr*, Nov. 1949, **21** (12), C-6.—The 7500-b.d. Continental Oil Refinery at Billings, Montana, is designed to handle crude of 28 A.P.I. and 2·2% sulphur. Stainless-steel linings are used in the crude fractionator, the desulphurizer reactor and fractionator, and the catalytic-

cracking fractionating column. Stainless steel is also used in most of the heat exchangers, while the Perco liquid copper sweetening unit uses bakelite plastic lines and glass-lined valves. Nearly half the crude is taken overhead into the catalytic desulphurization unit, which uses the same catalyst and regenerator as the cat cracker, and then the vapours are fractionated. To reduce carbon resulting from charging the reduced crude to the cat cracker the bottoms are deasphalted with liquid propane in a countercurrent extraction tower, a 6 : 1 ratio being used. The asphalt on recovery is blended to give a marketable fuel oil. To reduce further the sulphur content a Girbotol treating unit, a caustic washing system, the Perco copper unit, and the doctor treating method are all used. Gasoline production is increased by the use of U.O.P. "solid phosphoric acid" catalyst unit, the reactors being of the tube and shell type. Inspection and true b.p. data on all the products are presented. G. K. A.

1842. Reduced crude decarbonization at modernized British American refinery. G. Weber. *Oil Gas J.*, 8.6.50, **49** (5), 54.—Principal additions to the Montreal East Refinery of British American Oil Co. Ltd., Canada, comprising a 14,500-b.d. crude-distillation unit, a propane-decarbonizing unit designed to handle 4350 b.d. of reduced crude, a 13,500-b.d. fluid catalytic cracking unit, and facilities for light-ends recovery and polymerization are described.

The addition of 1,784,000 brl of crude and product storage gives the plant a total storage capacity of 4,138,000 brl.

Auxiliary additions include a 50-kW turbo-electric generator to maintain all instruments, and new boiler of 75,000 lb/hr rating installed in the open. G. A. C.

1843. Gasoline plant emphasizes compactness. J. C. Albright. *Petrol. Engr*, Sept. 1949, **21** (10), C-32.—Designed to handle 40 million cu. ft. of gas daily at an absorption column pressure of 450 p.s.i.g. the plant uses oil of 150 mol. wt. in a twenty-tray column, the rate of oil determining the amount of propane extraction. Ethane and methane are removed from the rich oil by an de-ethanizer and a re-absorber built as one unit one on top of the other. The rich oil is directly heated to 500° F for stripping in conventional equipment. Hot oil is used for heating throughout, steam required being generated in heat exchangers with the 500° F oil. G. K. A.

1844. Charts for dished head areas. T. G. Hicks. *Petrol. Engr*, Nov. 1949, **21** (12), C-34.—The area of a dished head is often required, and it is not given in standard tables. Two charts are given based on the relationship Area $= KR_D^2$, where R_D is the radius of the dishing and K is a constant which depends on the shape of the head and has been derived mathematically. Two examples are given to illustrate the use of the charts. G. K. A.

1845. Nomograms in the design of heat transfer equipment. J. H. Ellinger. *Industr. Chem.*, 1940, **26**, 7–12; 99–108.—General considerations in nomogram design are discussed, and a detailed example of nomogram derivation given for the expression $Gr^p = V$, based on method of determinants, where Gr is Grashof No. and p a variable index. By combining as a single factor K all those quantities in the Grashof No. specific to the fluid at a given temp the formula $d^3\Delta t = KGr = W$ is derived, where d is the tube dia, Δt the temp diff, and W an intermediate nomogram scale val. The nomogram is then computed in three stages, two of which consist of three parallel scales (one scale being common to both stages) and the third an N-type scale, *i.e.*, the centre scale at an angle to the other two. Several nomograms computed by these principles are then reproduced, designed to reduce lengthy calculations in connexion with tubular heat exchangers. Included are nomograms for assessing: (*a*) heat-transfer coeff for film-type condesation of saturated vapour on horizontal and vertical tubes; (*b*) heat-transfer coeff for fluid films under conditions of natural and forced convection in various types of apparatus; (*c*) overall transfer coeff, allowing empirically for fouling factors; (*d*) complete exchanger size and tube lay-out. The nomograms are intended to assist particularly in estimating effect of varying one or more factors in final exchanger design. A. C.

1846. Admiralty condenser and heat-exchanger tubing in oil refinery service. W. Lynes. *Petrol. Engr*, Nov. 1949, **21** (12), C-42.—Admiralty brass, 70 copper, 1 tin,

and 29 zinc, is standard for heat-exchanger and condenser tubing. Its susceptibility to dezincification is inhibited by the addition of traces of arsenic, antimony, and phosphorus. Failure of the tubes is by dezincification, corrosion fatigue (cracking across the grains), and stress corrosion (cracking is intergranular). Analysis of failure of a number of tubes on service shows that plain Admiralty brass failures by dezincification, intergranular corrosion, and intergranular cracking are rare in refinery and power-station use, but transgranular cracking is an important cause of failure in refinery use. Transgranular cracking is the result of corrosion fatigue. Important causes may be sulphur corrosion, stresses due to vibration from machinery, or uneven flow of fluid concentrating at the base of corrosion pits. As an aid to lengthening the life of tubing in such instances, the unit should be insulated from vibration, more supports used for the tubes, and heavier-gauge tubes should be employed or chemical control to prevent initial corrosion and formation of a pit. The article is illustrated with micro-photographs of sections of tube wall. G. K. A.

1847. Natural frequencies of compressor and engine manifolds. E. F. Murphy. *Refiner*, July 1949, **28** (7), 151–6.—Noise, piping vibration, and loss of performance may result if the natural frequency of a compressor piping system equals a component of the pressure waves set up by the intermittent puffs of gas passing through intake or exhaust valves. This paper makes use of the analogy between these waves and electrical waves in developing a method for predicting the natural frequencies of piping systems. The method is applied to piping systems experimentally examined by others. The agreement is close, often within 1%.

Indiscriminate adding of receiver vol may be dangerous. The use of an orifice is wasteful and may be dangerous but a low-loss muffler can be designed by simple experiments. W. E. M.

1848. Split flow gas sweetening unit. J. S. Bellah, R. V. Mertz, and J. W. Kilmer. *Refiner*, June 1949, **28** (6), 154–9.—A new casinghead gasoline plant is described, designed to handle initially, 90 million cu. ft/day. An increased capacity up to 120 million cu. ft/day is possible by the addition of a small amount of equipment. Design recovery of liq products in gal/day is as follows: propane, 50,000; butanes, 92,000; gasoline, 100,000. Residue gas is sold. Interesting features include: (*a*) a split-flow girbotol unit to sweeten the field gas; (*b*) a fractionating re-absorber to de-ethanize the rich oil—requiring only one stripping still and no separate de-ethanizer; (c) indirect heating system using oil as the medium, supplying 90% of the process heating load. Recovery is as follows: propane, 32%; butanes, 85%; pentanes, etc., 99%. W. E. M.

1849. Safe flare stack ignition. W. A. McElhannon and O. L. Clevenger. *Petrol. Process.*, 1950, **5** (4), 397–8.—A Humble Oil & Refining Co. patent method of igniting waste gas at a stack top is described with diagrams. This comprises a 1-in pilot gas-line running from ground to stack top, and a 10 ft long section of 2-in pipe adjacent to the pilot line at the stack top. The 2-in pipe is perforated at the lower end, and is connected to a gas supply by a ¾-in line. A heater element above the perforations ignites a supply of gas inside the 2-in pipe, which then ignites the pilot gas jet. D. W. F.

1850. Wall flame rotary oilburners. Part II. Installation methods and procedures. D. L. Wooden and P. G. Coale. *Fuel Oil & Oil Heat*, June 1950, **9** (6), 64.—A pre-installation survey is advised, and items to be determined are listed. Information obtained by the survey should be passed on to the installation crew.

It has been found that three men comprise the most advantageous size of crew for the average domestic installation. Firing and adjusting of the burner, and testing o controls should be the responsibility of an inspector.

The first step in burner installation is the making of the sheet-metal hearth plate. Two typical lay-outs for a round and a rectangular hearth plate are illustrated. The next step is the assembly or the formation of the flame ring outside the boiler. In water- and steam-boilers the flame-ring diameter should be determined with enough allowance to provide a ½- to ¾-in space between band and boiler wall; in gravity warm-air furnaces the allowance should be ½ in.

The hearth plate is inserted in the boiler, and then the burner. Levelling of the burner is necessary. One of the most important steps in laying a good hearth is sealing the hearth plate. The placing of the flame ring is described. An air leak between ring and hearth would cause a smoky fire behind the ring, carbon would be deposited and cause the burner to fail. The tank must be mounted sufficiently high so that the oil-level line will not be less than 10 in above the outlet of the fuel tube on the burner, and a greater height is desirable. Numerous diagrams are included.

D. K.

1851. A method of conditioning of refinery effluent for re-use and disposal. F. M. Faulconer, D. L. McCann, and H. L. Bedell. *Petrol. Engr*, Nov. 1949, **21** (12), C-26.—This system was designed for an inland skimming and cracking unit. The total system contains 1,500,000 gal of water and has an effluent rate of 1500 g.p.m. The raw water after settling is treated with lime, soda ash, and ferric sulphate in a reactor, passed through anthracite filters to the treated-water storage in which the pH is controlled. Cooling water blow down, the flow of which is controlled to limit the concentration of solid in the cooling-water system is treated with ferric sulphate or ammonium sulphate in a reactor, passed through anthracite filters and discharged into the river. The alkylation effluent and acid plant washings pass to a lime pit and then to a reactor where ferric sulphate is added to precipitate the solids. After filtering the water is added to the raw-water intake. Sludge is drawn off all the settlers, dumped to dry out, and is then disposed. The effluent water contains ammonia ions and has to be diluted with at least three times the volume of river water to be safe for fish, the effluent is clear, free of oil and phenol, and is amber in colour from organic material. The oxygen demand of the river is only temporarily affected. G. K. A.

Distillation.

1852. Alignment chart for calculating relative volatility. W. C. Frisbe. *Refiner*, 1950, **29** (1), 137.—A nomograph is presented for solving the equation of F. W. Melpolder and C. E. Headington (*Indust. Engng Chem.*, 1947, **39**, 763).

$$\text{Log } \alpha = \frac{\Delta T}{T}\left(7{\cdot}30 - 1{\cdot}15 \log P + \frac{T}{179 \log P}\right)$$

where α = relative volatility;
P = absolute pressure in mm Hg;
T = average boiling point of mixture ° K;
ΔT = the difference in b.ps. of the two components ° C.

The method is applicable only to a binary system or to the two key components of a mixture, where there is no appreciable deviation from Raoult's Law.

R. W. G.

1853. High efficiency in contacting produced by new bubble cap. Anon. *Petrol. Process*, 1950, **5** (4), 401.—A diagram and brief description of operation are given of an improved tray unit covered by U.S.P. 2,497,136 of 14.2.1950 assigned to Standard Oil Development Co. (J. A. Patterson). Each unit consists of two trays, the lower one containing nozzles which protrude into the base of cylindrical risers supported in the second tray a short distance above the lower one. Downcoming liq flows into the space between plates, and whilst passing up through the risers becomes intimately mixed with vapour issuing from the lower tray nozzles. D. W. F.

1854. Start-up procedure for a natural gasoline plant. T. D. Tabbert. *Refiner*, July 1949, **28** (7), 113–17.—The starting up of a typical natural gasoline plant is described, and each unit is discussed in general terms. W. E. M.

1855. Calculation of minimum reflux in distillation columns. R. N. Shiras, D. N. Hanson, and C. H. Gibson. *Industr. Engng Chem.*, 1950, **42** (5), 871–6.—Calculation of min reflux ratios in distillation of multicomponent mixtures is described by three methods. First method depends on two equations published by Underwood in 1932

and is simple, but accurate only for a restricted class of separations. Second method is extensive and is an elaboration of a recent method of Underwood using the ϕ function. Constant reflux and volatility ratio is an essential postulate to this method, which can also be applied approximately to all normal design problems. Last method adapts the plate-by-plate calculations of Thiele and Geddes for finite plate columns. This method allows for variable reflux and volatility ratio, and includes all types of separation. Disadvantage of this latter is that it is more time-consuming than is usually convenient for industrial design. R. G. T.

1856. Minimum reflux ratio for multicomponent distillation. (Correspondence.) J. A. May. *Industr. Engng Chem.*, 1950, **42** (5), 929–30. (*See Industr. Engng Chem.*, 1949, **41**, 2775.)—Observation has enabled development of simple equations to solve case . . . *abc/def* . . . when $q = 1$ or $q = 0$. An example calculation and indicated development of the equations are given which eliminate the need for graphical assistance. R. G. T.

1857. Equilibrium constants for high boiling hydrocarbon fractions of varying characterization factors. F. H. Poettman and B. J. Mayland.—*Refiner*, July 1949, **28** (7), 101–12.—Data and methods are presented enabling vapour liq equilibrium calculations to be made with oils having normal b.ps. up to 1000° F. Equilibrium vaporization constants are used, based on the b.ps. and characterization factors of individual fractions. The procedure is similar to that used at present, but is extended beyond the limits where calculations with individual hydrocarbon components become too complicated.

The data are presented in twelve charts. Pressure is plotted against equilibrium vaporization constant for temps up to 1000° F, for characterization factors from 10·5 to 12·5, and between normal b.ps. of 300° and 1000° F. W. E. M.

1858. Hydrocarbon azeotropes with acetonitrile. R. B. Bishop and W. I. Denton. *Industr. Engng Chem.*, 1950, **42** (5,) 883–5.—Present investigation of azeotropes between acetonitrile and hydrocarbons aims at using acetonitrile as a selective separating agent. Composition and b.p. of the azeotropes of acetonitrile with representative aromatics, *n*-olefins, parafins, and naphthenes were determined. Benzene and toluene are shown to be the only aromatics which form azeotropes. Paraffins and naphthenes up to C_9 form azeotropes and can be separated from toluene. Hydrocarbons with branched chains exist in azeotropes with acetonitrile in greater proportions than straight-chain hydrocarbons. Only the aromatics gave complete miscibility in the condensed azeotrope—for non-miscible azeotropes, b.p. and composition were calc from v.p. curves of the pure components assuming complete miscibility. Comparison of calc and observed data showed deviation due to partial miscibility. R. G. T.

1859. Patent. C. P. Stanley, assr to Phillips Petroleum Co. U.S.P. 2,504,464, 18.4.50. Describes a method for the control of distillation columns. C. F. S.

Absorption and Adsorption.

1860. New Mamon field process plant has facilities for 7,000 M.c.f. B. C. Barnes. *Oil Gas J.*, 22.6.50, **49** (7), 189.—The process facilities for handling 7000 M.c.f. per day of oil-well gas at the Magnola Petroleum Co's Evangeline plant, La, are described.

Design of extraction efficiency is 45% for propane and 95% for butane from the feed. Process employed is straightforward absorption–distillation–fractionation cycle. G. A. C.

1861. Boussens gasoline plant. F. de Boulard. *World Petrol.*, 1950, **21** (6), 27–9.—A general description of the high-pressure gas-processing and dehydration plant on the St Marcet (France) field. Products include propane, butane, kerosine, tractor fuel, or absorption oil. Distribution of the gas to neighbouring areas is described. E. B.

1862. Fluidized solids technique adopted for adsorption. P. J. Gaylor. *Petrol. Process.*, 1950, **5** (4), 404.—Separation of liquid components from gas or vapour streams

is achieved by a fluidized adsorbent such as silica-gel in a process covered by U.S.P. 2,493,911 assigned to Pan American Refining Corp. D. W. F.

1863. Patent. J. W. Catchum, assr to Phillips Petroleum Co. U.S.P., 2,504,429, 18.4.50. Recovery of hydrocarbons from natural gas. C. F. S.

Cracking.

1864. Platforming. V. Haensel. *Petrol. Process.*, 1950, **5** (4), 356–60. (*Western Petroleum Refiners Assn. San Antonio*, Mar. 27–29, 1950.)—Various aspects of platforming are considered. The three major chemical reactions occurring are: (*a*) dehydrogeneration of naphthenic hydrocarbons to the corresponding aromatics; (*b*) hydrocracking, the decomposition of high-mol.-wt. hydrocarbons into low-mol.-wt. compounds involving a simultaneous cracking, isomerization, hydrogenation reaction; (*c*) isomerization. Other important reactions occurring are dehydrocyclization (the direct conversion of paraffins to aromatics) and desulphurization. The four major operating variables are reactor temp, pressure, brl of charge/hr/brl catalyst, and hydrogen-recycle rate. Test data are given for different charges treated under different conditions. Properties of the platformate are discussed, and a brief economic analysis of a unit is given. D. W. F.

1865. Platforming. Operating results and design details of first commercial installation of this new catalytic reforming process for upgrading straight-runs. W. F. Bland. *Petrol. Process.*, 1950, **5** (4), 351–5.—A description is given of the first commercial U.O.P. platforming unit in operation at the Muskegon, Mich., refinery of the Old Dutch Refining Company for the conversion of low-quality straight-run gasoline into high O.N. fuel. Capacity is 1500 b.d., with a product yield of 90–95% gasoline with a clear Research rating of about 79–83 or 96 + 3 cc T.E.L. Lead susceptibility is good, due to the removal of more than 90% of the feed sulphur content. U.O.P. cost estimates for a similar plant size and product are given as about 30–37 cents/brl feed.

The charge is first fractionated to remove light and heavy ends, the intermediate cuts being passed to a heater, where the temp and pressure are raised to 900–950° F and 700–750 p.s.i. The heated charge meets recycle gas (mainly hydrogen) and enters the reactors containing a special platinum catalyst, and the product is then stabilized. D. W. F.

1866. Simplified moving bed catalytic cracking. P. J. Gaylor. *Petrol. Process.*, 1950, **5** (4), 404.—A simplified method of catalyst regeneration is indicated in U.S.P. 2,490,975 assigned to Phillips Petroleum Co. The method involves a combustible support of charcoal, coke, sawdust, etc., of 9–14 mesh for the cracking catalyst, the latter being added in the form of a 10% slurry, when it is activated, followed by dehydration before entering the reactor. D. W. F.

1867. Panhandle's "kitten cracker" has 1,250 bbl daily charge. R. W. Jacobs. *Oil Gas J.*, 29.6.50, **49** (8), 81.—The new fluid catalytic cracker at Wichita Falls, Texas, charging virgin gas oil to produce 50% of 93·0 octane, 10 R.V.P. gasoline on 68% conversion is described.

A small still of 15,000,000 B.Th.U/hr capacity cuts out 1300 b.s.d. of 33·0° A.P.I. gas oil for the catalytic cracker from the North Texas crude processed on the Dubbs unit.

Flow sheets and a summary of products are given. G. A. C.

1868. Chemistry of clay cracking catalysts. C. L. Thomas, J. Hickley, and G. Stecker. *Industr. Engng Chem.*, 1950, **42** (5), 866–71.—Acid treatment of Montmorillonite clays was shown to first increase cat activity and then decrease it. The acid acts by removing metal atoms (*e.g.*, Al) from the central layer of the crystal structure, and these metal atoms are in octahedral linkage with oxygen atoms. Authors postulate that removal of one of two octahedral atoms removes two OH groups and leaves the other atom in tetrahedral linkage. The crystal lattice is thus left with a negative charge balanced by a H ion, which is assumed to be the source of cat activity. A correlation is shown

between acidity and cat activity. A carbonium ion mechanism has been postulated for the cracking reaction; and the acidity theory here shown supports this mechanism.
R. G. T.

1869. Patents. H. A. Shabaker, assr to Houdry Process Corpn. U.S.P. 2,504,158, 18.4.50. Hydrocarbon conversion with Eccles kaolin under catalytic cracking conditions, the catalyst containing on dry-weight basis about 43–47% SiO_2 and 41–35% Al_2O_3.

H. J. Hepp, assr to Phillips Petroleum Co. U.S.P. 2,504,415, 18.4.50. An improved catalytic cracking and reforming process for the manufacture of motor fuels from a feedstock mixture 50–70% by vol of naphtha, 5–15% by vol of C_3 and C_4 gases and 15–45% of refractory gas oil.

F. H. Blanding, assr to Standard Oil Development Co. U.S.P. 2,506,291, 2.5.50. A process for catalytic cracking of hydrocarbons to produce higher yields of high octane gasoline.
C. F. S.

Alkylation.

1870. Patents. S. H. McAllister and E. F. Bullard, assrs to Shell Development Co. U.S.P. 2,505,644, 25.4.50. Production of high anti-knock motor fuels by alkylation, from still gases containing a mixture of *iso*paraffin, *n*-paraffin, and olefin and using a sulphuric acid catalyst.

A. N. Sachanen, and P. D. Caesar, assrs to Socony-Vacuum Oil Co. Inc. U.S.P. 2,506,551, 2.5.50. A process for the alkylation of benzene with an alkyl chloride.
C. F. S.

Isomerization.

1871. Patents. B. H. Shoemaker and E. L. Evering, assrs to Standard Oil Co., Indiana. U.S.P. 2,504,280, 18.4.50. Process for the isomerization of light hydrocarbons, which comprises admixing with a paraffin hydrocarbon a low-boiling cyclic hydrocarbon, and then contacting the mixture with at least an equal weight of anhydrous hydrogen fluoride catalyst at a temp of about 300–400° F.

W. E. Ross and P. Pezzaglia, assrs to Shell Development Co. U.S.P. 2,505,792, 2.5.50. The production of *cyclo*hexane from a mixture comprising methyl*cyclo*pentane and open-chain hexanes of normal and branched structure and benzene, by first of all fractionating and then isomerizing.
C. F. S.

Chemical and Physical Refining.

1872. Important filter and catalyst materials are manufactured in Mississippi. A. L. Foster. *Petrol. Engr*, Sept. 1949, **21** (10), C-39.—The Filtrol Corporation's plant at Jackson produces filter 'clays' and catalysts for use in the petroleum industry. Two types of the latter are produced, the natural, for which the raw material is mixed, crushed, and sized, and the synthetic, usually made by precipitating the metal oxide from its water solution. These are formed as pellets for Houdry and T.C.C. processes and a dust up to 200 mesh for fluid-type processes. Other uses are for colour improvement and an aid to filtration for lubricating oils, and for stabilization by removal of highly cracked material.
G. K. A.

1873. Desulphurization of heptane solutions of organic sulphur compounds. J. R. Meadow and T. A. White. *Industr. Engng Chem.*, 1950, **42** (5), 926–9.—Desulphurizing tests were carried out for various reagents on sulphur compounds in *n*-heptane. Nitrogen peroxide in 95% H_2SO_4 and anhydrous H.F. were found most effective. Conc H_2SO_4 showed strong action with thiophenes and sulphides, but not with mercaptans and disulphides, which were very soluble in the NO_2 solution. Anhydrous $AlCl_3$ and $AlBr_3$ were not found to be very effective at 20° C, 10 min contact time, and 0·3–1·2 mol Al halide per mol sulphur compound.
R. G. T.

Special Processes.

1874. Chemical engineering aspects of the Fischer–Tropsch process. C. C. Hall and A. H. Taylor. *Trans. Inst. chem. Engrs.*, 1947, **25**, 5.—Many features of Fischer–Tropsch process plant design and operation in Germany of interest to chemical engineers are described in some detail. Of the nine German plants seven used coke or coke-oven gas, and the rest used brown coal as the raw material. Hydrogen sulphide was removed from the gas by the normal iron oxide process, using Luxmasse as the contact material. The organic sulphur compounds were removed by passing the preheated gas at 300° through two towers containing granules composed of 70% Luxmasse and 30% Na_2CO_3. The sulphur compound was retained in the granule as Na_2SO_4. The purified gas mixture was then passed either at atm pressure or at nine to eleven atm gauge pressure (medium-pressure process) over a cobalt catalyst at a temp in the range 190–200° C, using two or three stages of treatment. The reaction products consisted mainly of straight-chain paraffins and olefins ranging from propane to wax of high melting point. These were separated from the residual gas and formed into fractions by distillation. These products were either sold as such or converted, by further processing, into products such as lubricating oil, alcohols, fatty acids, etc.

J. T.

1875. Making chemicals in Stanlow, England. A. L. Foster. *Petrol. Engr*, Oct 1949, **21** (11), C-22.—This plant, designed to produce 24,000 tons/annum of solvents, will get its raw material—cracked gases—from an adjacent new refinery. All the normal processes are included and the initial range of products will include *iso*propyl, *iso*propyl ether, acetone, diacetone, methyl-*i*-butyl ketone, mesityl oxide, *sec*-butyl alcohol, and methyl ethyl ketone. The pumps used are mainly Sigmund centrifugals and pump design is standardized to ease maintenance problems. Thus three basic pump designs are used; a single-stage, a two-stage, and a multi-stage barrel pump, and over three-quarters of all pumps have only two sizes of bearing assemblies. For handling hydrocarbon–sulphuric acid mixtures the pump used, like most of the pumps, has the stuffing-box end under suction and sulphuric acid as the sealing fluid, the parts being lead-lined. An internal bearing is used and bearing bushes and shaft-protecting sleeves are faced with Colmonoy No. 6. Diffusers are used on most pumps to reduce radial thrust on the shaft and to minimize leakage.

G. K. A.

1876. Ethylene glycol via ethylene chlorohydrin. P. W. Sherwood. *Refiner*, July 1949, **28** (7), 120–4.—This article gives details of the process involving the preparation and purification of ethylene oxide and subsequent conversion to glycol.

W. E. M.

1877. Extraction of toluene from petroleum with water as solvent. Anon. *Ingenieur*, 30.6.50, **62** (26), Ch.-40.—In order to obtain the conditions required, a temp of 302° C and a pressure of 200 atm is called for. These factors, along with the rather high number of theoretical stages required, render the practical development of such a process a very doubtful proposition.

R. R.

1878. Patents. E. J. R. Sorf, assr to Socony-Vacuum Oil Co. Inc. U.S.P. 2,504,102, 18.4.50. Revivifying sulphur-killed catalysts by subjecting the catalyst after removal of carbonaceous contaminants, by burning to a temp of at least 1050° F but not less than 1425° F for at least 5 hr in an atm of low moisture content.

P. M. Arnold, assr to Phillips Petroleum Co. U.S.P. 2,504,172, 18.4.50. Process for the dealkylation of alkyl pyridines by treating with a reactive aromatic compound and a dealkylation catalyst at a temp between 850° and 1200° F.

R. C. Archibald and R. A. Trimble, assrs to Shell Development Co. U.S.P. 2,504,618, 18.4.50. Process for producing alcohols by hydration of olefins in presence of an HF treated, activated montmorillonite catalyst.

J. T. Harlan, assr to Shell Development Co. U.S.P. 2,504,682, 18.4.50. Production of oxygenated compounds comprising the synthesis of a carbonol by the Oxo process.

D. Harman, assr to Shell Development Co. U.S.P. 2,504,411, 18.4.50. Improvement in the process for the production of alkyl sulphonates by the reaction of an olefin

with bisulphite ions in aqueous solution, which comprises using temps between 60° and 120° C in presence of a pair of the groups :—

2 : 2-bis(tertiary-butylperoxy) butane with methanol.
tertiary-butyl perbenzoate with methanol.
tertiary-butyl perbenzoate with hexanolamine.
tertiary-butyl perbenzoate with ethanol.
tertiary-butyl perbenzoate with pyridine
2 : 2-bis(tertiary-butylperoxy) butane with pyridine.
di-tertiary-butyl peroxide with pyridine.

A. Clark, assr to Phillips Petroleum Co. U.S.P. 2,506,065, 2.5.50. A combination process for the production of diolefins and motor fuel from CO and H_2 using a Fischer–Tropsch catalyst.

P. C. Keith, assr to Hydrocarbon Research Inc. U.S.P. 2,506,221, 2.5.50. The process for the catalytic synthesis of hydrocarbons from CO and H_2.

E. T. Layng, assr to Hydrocarbon Research Inc. U.S.P. 2,506,226, 2.5.50. Stainless-steel catalyst for use in the process for the catalytic synthesis of hydrocarbons from CO and H_2.

L. K. Beach, J. F. Nelson, and J. Stewart, assrs to Standard Oil Development Co. U.S.P. 2,506,289, 2.5.50. Process for separation of isomers by reacting mercuric acetate with a mixture of isomeric polyalkyl benzenoid hydrocarbons including *ortho-*, *meta-*, and *para*-isomers. C. F. S.

Metering and Control.

1879. Special purpose pumping equipment. Anon. *Mech. World*, 30.6.50, **127** (3311), 738.—The paper describes a pumping set recently supplied for the hydraulic testing of air-pressure reservoirs. The equipment consists of a Hamworthy size B1 non-self-priming centrifugal pump capable of delivering 1200 gal/hr of water against a total head of 23 ft when running at 1420 r.p.m., a ram pump, $\frac{7}{8}$-in bore × 1-in stroke, capable of delivering 15 gal/hr of water against a total pressure of 500 p.s.i. when running at 135 r.p.m., and 1-b.h.p. electric motor for a 400/440-V, three-phase, 50-c supply, 1420 r.p.m. with double-shaft extension and a 10·5/1 worm reduction gear. The centrifugal pump is direct-coupled to one shaft extension of the motor, and the ram pump driven from the other through the worm reduction gear, the whole set being mounted on a fabricated steel bedplate. The set provides the means for the rapid hydraulic testing of air-receivers and similar pressure vessels of large volume.
A. S.

1880. Analytical instruments in automatic control systems. N. Gildersleeve. *Refiner*, June 1949, **28** (6), 133–40.—Analytical instruments are classified in four main groups: (1) Mass spectrometry may be used for continuous recording of certain mass concentrations and using a multi-point, up to eight different mass concentrations may be recorded continuously in a continuous sampling feed. As a controller, the spectrometer can record a single mass continuously and use standard pneumatic or electrical control from the instrument. (2) Absorption spectroscopy instruments—X-ray, ultra-violet, and infra-red. All these types may be coupled to automatic controllers, and several examples are given. (3) Analytical methods depending upon physical properties of materials, *e.g.*, acoustical frequency, heat of combustion, density, and thermal conductivity. These methods require single overall measurements and are applicable when one component has a physical characteristic widely different from those of the other components. *E.g.*, thermal conductivity for hydrogen. (4) Special instruments designed for definite components: (*a*) dew-point recorders and controllers which depend on the reflection of light from a mirror until misted by condensation; (*b*) magno-thermal oxygen analyser which depends on the unusual paramagnetic properties of oxygen; (*c*) photo-electric turbidity recorders and controllers.

The article is concluded by some suggestions for new types of controllers and with diagrams for proposed applications: (*a*) process-control spectrometer for a depropanizer column; (*b*) control of atmosphere-gas producers; (*c*) X-ray system for automatic blending of T.E.L. with gasoline. W. E. M.

1881. Refinery valve design reduces sticking at coking conditions. Anon. *Petrol. Process*, 1950, **5** (4), 401.—A gate-type valve, covered by U.S.P. 2,496,452 of 7.2.50 assigned to McEvoy Co., Houston (R. Eichenberg and F. Gober), designed to overcome sticking due to coke formation when used under cracking conditions is described with a diagram. To the base of the valve body is screwed a finned cylindrical casting with a removable bottom head forming a chamber to receive the gate when in the closed position and any coke formed in the valve. D. W. F.

1882. The control valve—its application. J. A. Pellettere, *Petrol. Engr*, Nov. 1949, **21** (12), C-21.—Control-valve applications may be divided into: (*a*) Where the valve is the load and the pressure drop across the valve is almost constant for all rates of throughput. Here sizing is simple (see makers' catalogues), the valve should pass the max flow required plus the safety factor. A linear plug is suitable. A linear characteristic valve produces a flow capacity approx proportional to the per cent lift. (*b*) Where the valve is only a minor part of the load and the pressure drop across the valve varies with throughput. Then the valve size should be sufficient for twice the design flow with a pressure drop of 15% of the total available head loss. If more than 6% excess of design flow is required, more than the 15% head loss must be provided for the valve. A logarithmic plug valve should be used. This gives 15% capacity at 50% lift, and the unit per cent change in flow per unit change in lift is approx constant. In this system the valve is a source of power loss if it is in series with the load. To avoid this the control in the line can be replaced by an auxiliary device such as a governor, unloader, or automatic clutch. G. K. A.

1883. Nomograph for determining Reynolds number. T. H. Arnold. *Refiner*, 1950, **29** (3), 155–6.—A nomograph is presented for determining Reynolds number. R. W. G.

1884. Ultimate yield nomograph for recycle processes. A. D. Synder and D. S. Davies. *Refiner*, 1950, **29** (1), 134.—To determine the most effective economical relation between the yield of product and the cycle stock per pass, the ultimate yield must be known.

If x = fraction yield of product per pass, y = fractional amount of cycle stock per pass, S = fractional ultimate yield of product.

$$\text{Then } S = \frac{x}{1 - y}$$

A nomograph is given for this calculation. R. W. G.

1885. Graphic panels. W. C. Uhl. *Petrol. Proccess.*, 1950, **5** (4), 361–8.—The results of a recent survey of the trends in the use of graphic panels by oil companies carried out by *Petrol. Process.* are presented. This includes the historical development of the graphic panels and views expressed by various users. A number of recent panel installations are discussed, together with new instruments being developed for use with graphic panels. Facts revealed by the survey are: (*a*) cost of panels equal to or less than conventional instrument boards; (*b*) short installation time required; (*c*) smaller control buildings required; (*d*) better overall process control obtainable. D. W. F.

1886. Graphic panels help solve processing industry problems. G. E. Howard. *Refiner*, 1950, **29** (3), 107–9.—As the demand for better fuels has increased, refineries have required more accurate control of plant in order to improve product quality and to protect equipment. Hence, the growth of control rooms. Control-house costs, however, vary from $200 to $300 per linear foot.

Disturbances on complex plant must be quickly rectified, hence petroleum and chemical industry require: reduced panel-board size, increased quality control, improved supervision. To this end the graphic-type panel and compact instruments have been evolved. Typical high-speed temp, pressure, and speed transmitters are illustrated. R. W. G.

1887. Console-graphic panels. V. V. Tivy. *Refiner*, 1950, **29** (3), 102–6.—With the increase in instrumentation on refineries it is advisable to have a central control room

which provides a clean, dry location for the precision instruments. The particular requirements and features of the control room and the instruments therein are discussed.

A graphic-type panel has, as a background, a flow diagram of the plant. Only controllers and indicators are mounted on the main panel, recorders being mounted elsewhere. It is not as compact or flexible as the console-type panel, on which proper grouping of the instruments allows adequate " keying " of the controllers to different sections of the plant. R. W. G.

1888. Need for standardization of process instrument symbols. C. S. Beard. *Refiner*, 1950, **29** (3), 97–101.—Two figures illustrating the number of different symbols and abbreviations in current use for designating particular instruments show the need for standardization. The article illustrates and describes the symbols recommended by a standardization committee of the Instrument Society of America. Most abbreviations consist of two or three letters. The first representing the measured variable, *e.g.*, *T* for temperature, *P* for pressure, *L* for level; the second, the type of instrument, *e.g.*, *R* for recorder, *I* for indicator; the third, the function, *e.g.*, *C* for controller, *A* for alarm. Standard symbols are also depicted, most of which are self-explanatory. A flow diagram for a typical boiler installation fully instrumented is given as an example. R. W. G.

1889. Remote dial flowmeter. Anon. *Auto Engr*, June 1950, **40** (528), 214.—A self-contained, portable flowmeter, made by Dixon-Bate Ltd., for fuel-consumption readings is described, which has its measuring unit inserted in the fuel line of the engine. The indicating component is electrically operated, and is a normal instrument dial that can be placed at any convenient point. Normal flowmeter principles are used, but the varying height of the column in the metering tube is not measured as a dimension but provides a varying pressure due to increase or decrease of head. This small pressure variation is applied to a bellows unit which moves the slider of a rheostat unit, and so actuates an indicating instrument, of the fuel-tank contents-gauge type, having two opposing field coils. The measuring unit is a hermetically sealed container embodying the flowmeter and the pressure-sensitive variable resistance assembly. Readings with no more than 1% error are possible, and the pointer follows throttle movement or load variation very closely. The meter can also be used for any purpose where rate of flow is to be measured. A diagram of the assembly is included. U. N.

PRODUCTS.

Chemistry and Physics.

1890. Some properties of the calcium salts of the lower fatty acids. Part I. Viscosity. W. B. Bonner and C. G. Smith. *J. chem. Soc.*, May 1950, p. 1359.—The viscs of aqueous solutions of calcium acetate and of the calcium salts of other lower fatty acids were determined. It is suggested that the high visc of these salt solutions point to the formation of asymmetric anionic complexes similar to, but simpler than, the micelles formed in soap solutions. J. H. P.

1891. Sulphur in petroleum. III. Selected physical properties of some sulphur compounds. R. V. Helm, W. E. Haines, and J. S. Ball. *Bur. Mines Rep. Invest.* 4566, Nov. 1949.—Various physical properties of those sulphur compounds most likely to occur in petroleum and petroleum products are given. These include b.p.s, refractive indices, densities, freezing points, surface tensions, viscs, refractivity intercepts, specific dispersions, specific refractions and parachors. J. T.

1892. Aromatic sulphonation. Part I. The ionization constants of *p*-nitrotoluene, nitrobenzene, and *p*-chloronitrobenzene, and the activity function of oleum. J. C. D. Brand. *J. chem. Soc.*, Mar. 1950, p. 997.—Spectrometric determinations of the ionization constants (pKa) of *p*-nitrotoluene, nitrobenzene, and *p*-chloronitrobenzene are reported, and the acidity-function scale of sulphuric acid has been extended to include oleum containing up to 14% of sulphur trioxide. J. H. P.

1893. Aromatic sulphonation. Part II. Kinetics of sulphonation in fuming sulphuric acid. J. C. D. Brand. *J. chem. Soc.*, Mar. 1950, p. 1004.—The kinetics of sulphonation of some quaternary ammonium methyl sulphates, *p*-nitrotoluene, and nitrobenzene between 0° and 45° in oleum containing up to 33% sulphur trioxide have been studied. It is suggested that the governing step in sulphonation is: $SO_3H^+ + ArH = ArSO_3H + H^+$.

Relative values of the velocity coefficient of this reaction have been determined. J. H. P.

1894. Branched-chain super-esters. G. W. Youngson and H. W. Melville. *J. Chem. Soc.*, June 1950, p. 1613.—The synthesis of branched-chain super-ester molecules by the following method is described. Linear polyethylene adipate polymers were first prepared having terminal hydroxyl groups, and after slight degradation were then reacted with, for example: pentaerythritol. By end-group determinations and measurements of osmotic pressure, evidence of the formation of branched-chain molecules was obtained. The viscosity characteristics of these molecules were investigated and their significance discussed in some detail. J. H. P.

1895. Preparation of ethynylcarbinols from the bisulphite compounds of aldehydes and ketones. J. Cymerman and K. J. Wilks. *J. chem. Soc.*, Apr. 1940, p. 1208.—Ethynylcarbinols may be obtained in fair yields by reaction of the solid bisulphite compounds with sodium acetylide in liquid ammonia. J. H. P.

1896. The nitration of polystyrene. H. Zenftman. *J. chem. Soc.*, Mar. 1950, p. 982.—Polystyrene may be nitrated by those compositions of nitric or nitro-sulphuric acid in which it will dissolve. Substitution corresponding to one or two nitro-groups per styrene unit or to any intermediate degree of substitution can be obtained by control of the reaction conditions. The mol. wt. of the initial polystyrene has little influence on the nitrogen content of the final product, and nitration in sealed tubes at high temperatures does not yield nitropolystyrene of a higher degree of substitution than 2·0. Oxidative breakdown of the nitropolystyrene shows that only nuclear substitution occurs, with a maximum of two nitro-groups entering the benzene ring; the first at the *p*-position, the second randomly distributed along the polymer chain, entirely or predominantly in the *o*-position. The properties of various nitropolystyrenes are described. J. H. P.

1897. Effect of high pressures on the flammability of natural gas–air–nitrogen mixtures. G. W. Jones, R. E. Kennedy, and I. Spolan. *Bur. Mines Rep. Invest.*, 4557, Nov. 1949.—In recent years pressures exceeding 350 lb. gauge have been used in secondary-recovery processes, and pressures as high as 3000 lb gauge are anticipated in the future. The effect of pressures from atm to 3000 p.s.i. on the limits of flammability of natural-gas–air and natural-gas–air–nitrogen mixtures has been determined. It was found that pressure has a minor effect on the lower limit of flammability up to a pressure of 500 lb. Above 500 lb, increased pressure reduced the lower limit considerably. The lower limit of flammability of natural gas in air at atm pressure was 4·50% by vol and at 3000 p.s.i. was 3·15% by vol. Increased pressure has a marked effect on the upper limit of flammability. Natural gas has an upper limit of flammability of 14·2% by vol at atm pressure, 44·2% at 500 p.s.i., 52·9% at 1000 p.s.i., 59% at 2000 p.s.i., and 60% at 3000 p.s.i.

Since no combustible gas or vapour will burn or explode when the oxygen content of the atm is reduced below a certain definite value, which is specific for a given gas or vapour, it is possible to control or eliminate explosion hazards by means of oxygen control. The Bureau of Mines has accumulated considerable data on the application of this method for various hydrocarbon mixtures at atm pressure; however, no information is available as to the oxygen requirements to prevent explosions at high pressures.

The use of inert gases for the prevention of explosions at high pressures limits the choice to those gases that will not condense to liq. at the high pressures employed. Nitrogen is probably the only cheap and easily available gas found at pressures above 1000 p.s.i. The area of flammability of all possible mixtures of natural gas, air, and nitrogen was determined at atm, 500, 1000, and 2000 p.s.i. pressures. Graphs are

presented to show the max permissible oxygen percentage that will prevent explosion of natural-gas–air–nitrogen mixtures at high pressures. The following percentage values for oxygen must not be exceeded, 12·0% at atm pressure; 9·5% at 500 p.s.i.; 9·0% at 1000 p.s.i., and 8·5% at 2000 p.s.i. J. T.

1898. Mass spectra of nonanes. F. L. Mohler, L. Williamson, C. E. Wise, E. J. Wells, H. M. Dean, and E. G. Bloom. *Bur. Stand. J. Res., Wash.*, 1950, **44**, 291.—Mass spectra of thirty-five nonanes have been measured with a 180° consolidated mass spectrometer using 50-V and 70-V ionizing voltage but only measurements at 70 V are given. Sensitivity (current per unit pressure) at the max peak relative to *n*-butane and total ionization relative to *n*-butane are reported, as well as relative intensities for eighteen mass peaks.

Relations between molecular structure and mass spectra in nonanes, are similar to those in lighter saturated hydrocarbons. From published data for all isomers of paraffins with nine or less carbon atoms, some general relations between mass spectra and molecular structure are given. These are not, however, sufficient to deduce the structure from the observed spectrum. The analysis of mixtures of nonanes will, in general, be difficult or impossible unless the sample is a narrow cut containing few components. J. T.

1899. Synthesis and properties of two olefins, six paraffins, and their intermediates. T. W. Mears, A. Fookson, P. Pomerantz, E. H. Rich, C. S. Dussinger, and F. L. Howard. *Bur. Stand. J. Res., Wash.*, 1950, **44**, 299.—In order to study the desirability of certain hydrocarbon types in jet-engine fuels, eight aliphatic hydrocarbons have been prepared and purified. Their preparation and purification are described. Common physical constants are given for these hydrocarbons and for several intermediates synthesized for use in their preparation. J. T.

1900. Refractive index as a function of wavelength for sixty A.P.I.-N.B.S. hydrocarbons. A. F. Forziati. *Bur. Stand. J. Res., Wash.*, 1950, **44**, 373.—The refractive indices of sixty purified A.P.I.-N.B.S. hydrocarbons comprising seventeen paraffins, fourteen alkyl*cyclo*pentanes, eight alkyl*cyclo*hexanes, and twenty-one alkylbenzenes have been measured at 20°, 25°, and 30° C at seven wavelengths, helium 6678·1 and 5015·7 Å, hydrogen 6562·8 and 4861·3 Å, sodium 5892·6 Å, and mercury 5460·7 and 4358·3 Å.

The experimental data on the hydrocarbons were adjusted by means of a four-constant Hartman equation and a two-constant modified Cauchy equation. The computed refractive indices at the stated temp, together with the values of the specific dispersions and the constants of the Hartman and modified Cauchy equations applicable over the range of measurements are reported. J. T.

1901. Separation of 2 : 3-dimethylpentane, 1, *cis*-3-dimethyl*cyclo*pentane, and 3-ethylpentane from petroleum. A. R. Glasgow, Jr., C. B. Willingham, and F. D. Rossini. *Bur. Stand. J. Res., Wash.*, 1950, **44**, 411.—The separation of 3-ethylpentane and the fractionation of 2 : 3-dimethylpentane and 1, *cis*-3-dimethyl*cyclo*pentane from aromatic free fraction 89–94° C is described. These compounds, together with four hydrocarbons previously separated, constitute substantially all of the material of this particular petroleum fraction. For these compounds the normal boiling points (of high-purity samples not from the present investigation) and the estimated vol % in the original Ponca, Oklahoma, crude are as follows: 2 : 3-dimethylpentane, 89·78° C, 0·1%; 2-methylhexane, 90·05° C, 0·7%, 1, *trans*-3-dimethyl*cyclo*pentane 90·77° C, 0·9%; 1, *cis*-3-dimethyl*cyclo*pentane, 91·72° C, 0·2%; 3-methylhexane, 91·85° C, 0·5%, 1-*trans*-2-dimethyl*cyclo*pentane, 91·87° C, 0·5%; and 3-ethylpentane, 93·47° C, 0·05%. J. T.

1902. Graphic estimation of boiling point at reduced pressures. G. R. Robertson. *Chem. Education*, June 1950, **27** (6), 341.—Nomographs have been prepared to determine approximately the boiling point of a compound at reduced pressure. Two classes of problem can occur: (1) at least two boiling points may be known, at widely different pressures, therefore, only interpolation or extrapolation is necessary or (2)

only one boiling point is known. An example of each class is given. In the nomographs, scales have been chosen so that a plot of successive p (in mm) *vs* t (° C) will approx a straight line in the average case. For convenience in establishing slope, charts include a series of p–t lines of standard integral slope values for a group of hypothetical reference compounds all boiling at 130° C. Chart abscissa scale is laid out in units of log T, with such a scale all compounds with the same entropy of vaporization have p–t lines with the same slope. Two pressure scales are laid out in chart 1 based on *n*-hexane, a compound of low entropy of vaporization, and in chart 2 based on *n*-pentanol with a high entropy of vaporization. In each chart pressure lines are drawn such that the succession of co-ordinate boiling-point values for chosen standards between 1 and 760 mm fall approx on a straight line. Slight empirical correction of position and direction gives better agreement with a number of trial compounds. Since the 130 reference slopes are proportional to Trouton ratios, or entropy of vaporization, the Trouton scale was used to number the slopes with eleven integral values 20–30 recognized on the chart. As fixed points *n*-hexane was set as 22 and *n*-pentanol as 28. A table of slope values of various organic compounds is presented. The charts may also be used to detect certain errors in reported data. D. K.

1903. Significance of properties of petroleum products. XI. Colour. W. A. Woodrow. *I.P. Review*, 1950, **4**, 158.—Petroleum products cover the whole range of colour from colourless spirits to black bitumen. With the lighter ones there is a tendency for customers to become colour-conscious, although the quality may not necessarily depend on the colour. Colour is, however, often a guide to the origin of the crude. This is particularly the case in respect of " bloom " or fluorescence. It is possible to impart colour by dyes, and to remove colour by acid-earth treatment. The various methods of measuring colour are described. They all depend upon comparison with standards, and there are, therefore, difficulties in correlation. Most methods are visual, but photo-electric techniques are being developed. R. H.

1904. Significance of properties of petroleum products. XII. Burning tests. S. R. Hills. *I.P. Review*, 1950, **4**, 173.—The majority of lamps in use at the moment are of the wick-fed type. Their performance depends upon the lamp itself and upon the oil employed. The oil is important in the following ways :—

1. Hydrocarbon composition. The relative aromatics/paraffinics proportions affect performance.
2. Viscosity.
3. Char formation. This is caused predominantly by the high aromatic content.

Various methods of evaluating the burning quality of kerosine are described and standardized by the I.P. and by the A.S.T.M. The interpretation of results is also explained. R. H.

1905. Colloidal electrolytes. R. C. Merrill. *Chem. Education*, June 1950, **27** (6), 312.—Two general types of colloidal electrolyte may be distinguished. In the first the particle is a single molecule held together by primary covalent chemical bonds, and is of such a size that it comes within the colloidal range. The size of the particle is negligibly affected by change in temp, concentration, or by the addition of salts. This class includes most proteins (except when at their *iso*electric points), gum arabic, etc. The second type can be designated as " micellar," they show colligative effects equal to those of simple ionized salts. The size of the particle is greatly affected by change in temp, concentration, or the addition of salts. Examples of this type are soaps of saturated, unsaturated, branched, or straight-chain, cyclic or aromatic acids containing more than eight carbon atoms, which have been neutralized either with alkali-metal hydroxides or organic bases such as triethanolamine. This class is subdivided into anion-active and cation-active electrolytes.

The following properties of colloidal electrolytes are discussed in some detail : colligative effects, electrical conductivity, transference numbers, electromotive force, light scattering, X-ray investigations, solubilization, interaction with dyes, and other physico-chemical properties.

Other aspects considered are: surface phenomena, early work on soaps, phase behaviour in soaps, micelle formation in non-aqueous solutions. Many graphs and a table of critical concentrations for micelle formation of some soaps and detergents are presented. There are ninety-five literature references. D. K.

1906. Interpretation of " commercial weights " on the Continent. M. Jacob. *I.P. Review*, 1950, **4**, 141.—The " commercial weight " of a body is the result obtained by weighing it in the air surrounding it at the time, and using a weighing-machine and weights stamped as accurate by the authorities in the country concerned. This is not strictly accurate owing to the upthrust due to displaced air, and in any case varies from country to country owing to the different standards employed. From this the author goes on to emphasize the difference between mass and weight, and describes the nomenclature used to measure this and other related quantities. Density and the difference between the ml and cc are all explained. R. H.

1907. Viscosity of highly compressed fluids. Correlation with critical constants. L. Grunberg and A. H. Nissan. *Industr. Engng Chem.*, 1950, **42** (5), 885–91.—Previous correlations of visc and critical constants have used pressure as one of the parameters. By choosing density rather than pressure present investigation overcomes inaccuracies and interpolation difficulties in the critical region. A nomograph is produced relating ratio of visc of compressed fluid to visc at atm pressure, to reduced temp T/T_c and reduced density $\rho/\rho c$. It is applicable at high compressions near the crit pt. to $\pm$ 10%. Theoretical treatment assumes that momentum in highly compressed fluids may be transferred by two mechanisms, one translational, gas-type, and the other vibrational, liquid-type and produces the following equation :—

$$\mathrm{Log}_{10}\left[\frac{n_\rho}{n_A} - (1 - 0{\cdot}5\rho r)^{3/3}\right] - \frac{1}{4{\cdot}606T_r} = T{\cdot}855 + \log_{10} f(ps)$$

When $f(ps)$ is independent of the substance and dependent only on the reduced density. R. G. T.

Analysis and Testing.

1908. Swiss standards association. Group 102. Mineral oils and petroleum products. Anon. *Schweiz. Arch. Ang. Wiss. Tech.*, 1950, **16**, 147–59.—Draft Swiss standards are given for cold test (SNV 81107), foaming tendency (SNV 81050), distillation (SNV 81113), and octane and performance Nos. (SNV 81115). Cold test is carried out substantially according to I.P. 15/42, but temp recorded is that of actual solidification (*i.e.*, 3° C below pour point). Visc at solidification is *ca* 1500 stokes. Foam test uses Jena glass gas diffuser, vol foam on cessation of aeration and 10 min later is recorded for 25° and 95° C. Dist procedure is substantially according to I.P/A.S.T.M. Engine test standard is merely explanatory, reference being made to I.P/A.S.T.M. publications for test procedures. Main features of the latter are tabulated. V. B.

1909. A symposium on the testing of liquefied gases and light distillates, of lubricants, and of bitumen, and on standardization in oil measurement and sampling. H. Hyams, W. H. Thomas, R. S. Teale, and C. F. Jackson. *J. Inst. Petrol.*, 1950, **36**, 189–222.—The work of the four principal sub-committees of the Institute of Petroleum in these fields is reviewed briefly, and some indication of the work to be carried out in the future is given. A. R. W. B.

1910. The practical effects of particle size in bitumen emulsion. H. Whipp and F. W. Bernhardt. *Inst. Chem. Engns and Soc. Chem. Ind. Symposium on Particle Size Analysis*, Feb. 4, 1947.—Supplement to *Trans. Inst. chem. Engrs*, 1947, **25**.—An account of the effect of particle size on bitumen emulsions is given. The two types of emulsions considered are the soap-stabilized and the clay-stabilized emulsions.

The soap emulsions are influenced by particle size in the liquid state while the clay-stabilized emulsions are dependent on the dispersion in the dried film. Factors influencing the production of dispersions to a given particle size are outlined.

J. T.

1911. Analyses of some crude oils from the Middle East, South America, and Canada. O. C. Blade, E. L. Garton, and C. M. McKinney. *Bur. Mines Rep. Invest.*, 4657, Feb. 1950.—Thirty-five samples of crude oil from fields in seven countries of the Middle East and South America and from Canada have been analysed. J. T.

1912. Manometric precision procedure for determining the vapour pressure of aviation gasolines. W. C. Holliman and M. G. Barker. *Bur. Mines Rep. Invest.*, 4635, Jan. 1950.—The apparatus and procedure used in determining the v.p. of aviation gasoline are described in detail. It is based on the Reid method, the Bourdon gauge of which is replaced by a mercury manometer. It is designed for certain research problems, particularly in vapour-lock studies which require greater precision than that obtainable by the Reid v.p. method using a Bourdon gauge. The method gives a repeatability of $\pm$ 0·01 p.s.i. average deviation from the mean. The method was used in earlier surveys made by the National Bureau of Standards in co-operation with the co-ordinating Fuel and Equipment Committee of the Co-ordinating Research Council, Inc.; and was used in the Bureau of Mines surveys at the request of the co-operating organizations. J. T.

1913. Applications of a portable continuous smoke recorder. E. K. Von Brand. *Mech. Engr*, June 1950, **72** (6), 479.—The continuous smoke recorder described in the paper is one which has been developed to meet the need for a portable instrument of sufficient accuracy and versatility for continuous smoke measurements on small installations, especially domestic oil-burners. The instrument is based on the principle of filtering a known volume of flue gas to obtain a soot deposit on a filter, the optical density of this deposit then being a measure of the smoke content of the entire flue-gas stream. A continuous trace of smoke deposits is produced on a filter-tape by pulling the tape through a specially designed fixture interposed in the gas stream which is drawn continuously from the stack by a vacuum pump. The tape is kept moving by rolls geared to a synchronous motor to ensure uniform speed. The varying degrees of darkness of the trace furnish a measure of the smoke conditions under which the burner is operating, and a suitable time-scale is marked on the tape as it passes through the instrument to show the rate of change in smoking. Typical records produced by this instrument are given, and these reveal how useful the instrument could be in the detection of faults and troubles in the various fields of combustion. A. S.

1914. Peroxide determinations during the artificial ageing of insulating oils with copper catalyst. M. Zürcher and J. Lüder. *Bull. Schweiz. Elektrotechn. Ver.*, 1950, **41**, 511–15.—A quant colorimetric test for peroxides in oil is described. 0·5 g. $FeSO_4.7H_2O$ is dissolved in 10 ml 2N-H_2SO_4, 200 ml H_2O added, 25 ml of solution taken, mixed with 5 ml 50% KCNS, 35 ml H_2O, and 45 ml acetone (specially purified). 1 ml of oil under test is agitated (1 hr) with approx 18 ml of above reagent and peroxide No. (expressed as mg Fe'''/ml oil) estimated by colour comparison with blank brought to same colour by addition of known amount of $FeCl_3$. Series of peroxide tests made during ageing of transformer oil by standard Swiss seven-day procedure in Cu beaker showed that peroxide No. corresponds with tensile strength decrease of cotton fibres immersed in oil. Peroxide No/time curves clearly indicate induction period in oil oxidn and its extension by addition of oxidn inhibitor. Tests made using sol cat (Cu naphthenate containing 6·8% Cu) and replacing Cu beaker by porcelain show that sol cat gives similar oxidn results when used in concn equivalent to 0·001% (wt) Cu in oil. Using 0·01%, smaller peroxide Nos. were obtained than with lesser amount of cat, due to auto-catalytic breakdown of peroxides. It is considered that peroxide No. is a more reliable indication of oil deterioration than decrease of cotton strength. V. B.

1915. Methods for estimating octane number. H. D. Young. *Oil Gas J.*, 1.6.50, **49** (4), 81.—A report on studies made by the laboratory methods group of the diesel-fuels division of a Co-ordinating Research Council committee is summarized.

The study covers investigation of five indices currently used for estimating the cetane number of diesel fuels; and a modification of calculated cetane number is proposed. Better accuracy in estimating the cetane number of a wide range of fuels

between 15 and 85 is obtained by use of the modification, now designated as the C.F.R. Calculated Cetane Index.

An alignment chart to determine index value from A.P.I. gravity and mid-boiling point of a fuel is included. G. A. C.

1916. Batch distillation—characteristics and limitations of a batch still. L. E. Lloyd. *Refiner*, 1950, **29** (2), 135–45.—A continuous still gives theoretical separation (after allowance for plate efficiency) at near min reflux ratios with intermediate cut equal to hold-up per plate times the number of plates.

A batch still gives less than the theoretical separation at reflux ratios well above the min, large intermediate cut, and a poor yield of good material.

Laboratory experiments show that a greater yield of pure material can be obtained from a continuous still. On the other hand, a batch still is more suitable for separating a multicomponent mixture into several components, providing a high degree of purity is not required.

The effect of hold-up and kettle size on separation is discussed. When a column is operated batchwise with a very small charge, quite sharp breaks are obtained even with liquids which are difficult to separate. A series of figures illustrate the change in product composition due to change in bottoms composition during the batch distillation of a toluene–ethyl benzene system. R. W. G.

Crude Oil.

1917. Analyses of crude oils from some fields of southeastern United States. O. C. Blade and E. L. Garton. *Bur. Mines Rep. Invest.*, 4687, May 1950, 36 pp.—Information is given concerning the discovery and production (1), and analyses are recorded of fifty-one crude oils collected from the various fields, during a period of twenty-five years, in the following south eastern states of America: Alabama, Florida, Kentucky, Mississippi, Tennessee, and Virginia. W. H. C.

Gas.

1918. Underground storage of L.P. gases successfully performed at Carthage field plant of the Chicago Corp. C. B. Johnson. *Oil Gas J.*, 8.6.50, **49** (5), 50.—L.P. gases were successfully stored underground where the products could not come into contact with other hydrocarbons, in the Carthage field, Texas.

The L.P. gases could be withdrawn at will from storage, and volume recovered by uninterrupted natural flow indicates a much higher recovery efficiency when water-flood or mechanical-pumping means are provided. Underground storage succeeds economically. G. A. C.

1919. Ethylene production by cracking of propane–ethane mixtures. II. Tube selection and inspection. C. K. Buell and L. J. Weber. *Petrol. Process.*, 1950, **5** (4), 387–91. (*75th Annv. Colorado School of Mines, Golden, Colo., Sept.* 1949).—The main mechanical problem in gas-cracking plants is the catalytic formation of carbon in the furnace tubes, and subsequent erosion of the outlet-end return bends where the gas velocity is high. Carbon deposits can be removed by thermal shock or controlled internal combustion using air and steam. The more expensive 25–20 Cr–Ni alloy tubes withstand the conditions in the radiant section better than do 18–8 tubes, which, however, are found to be more resistant to erosion in the outlet section. The last foot of each of the outlet tubes can be further protected by reinforcing with extra wall thickness. With the aid of a chart constructed on a cost-and-life basis for a sixty-three-tube furnace it is shown that the last sixteen tubes should be of the 18–8 Cr–Ni alloy.

D. W. F.

Engine Fuels.

1920. Boiler fuels in marine diesel engines. II. Causes of carbon forming on fuel-valve nozzles. J. Lamb. *Motor Ship*, June 1950, **31** (365), 102.—Incomplete combustion of fuel in oil-engines is responsible for the formation of deposits which give rise to serious mechanical difficulties. The various types of deposit and how they are formed are described. Means of ensuring complete combustion by efficient fuel atomization

and injection, and the influence of needle-valve travel, are discussed. The case of the eight-cyl 4000 i.h.p. " Dromus " engine is quoted to show how deposit can be formed on the fuel-valve nozzles when the fuel is changed to one of lower visc, and methods used to overcome the trouble are illustrated. Boiler fuel within the 1500-sec visc range can be successfully burnt in four-cycle-type engines of the makes referred to in the earlier part of this paper, provided that it is first treated in the manner recommended. U. N.

1921. Regularities in the behaviour of anti-knock agents. H. Reichel. *Erdöl u. Kohle*, 1950, **3**, 227–30.—A comment on a paper by Hammerich (*Brennstoff Chem.*, 1949, **30**, 109; 159).—R. compares data given by H. with results obtained from the ethyl-blending chart developed by Hebl *et al* (*Indus. Engng Chem.*, 1939, **31**, 862); a more convenient form of the latter, in two stages, is proposed. Formulæ proposed by Hammerich for calculating lead susceptibility and the relationship of this criterion to the German " lead effectiveness No." is discussed; a curve relating the two standards is reproduced. Calculation methods are restricted to O.N. > 4040, which is adequate in practice. Procedures described can considerably curtail extent of engine tests required when examining a gasoline. V. B.

1922. Progress report on anti-detonant injection automotive engines. C. H. Van Hartesveldt. *Petrol. Engr*, Oct. 1949, **21** (11), C-37.—Vitane a mixture of 85% methyl alcohol, 15% of water, and 3 cc of T.E.L/gal is injected into the inlet manifold at full throttle to reduce the tendency to knock on lean mixtures. Increase in knock rating varies with the fuel—regular grade 80 O.N. with no vitane is improved to 90 with 15% vitane. The article lists the steps required to push the sales of this product and the effect on car design and on car-fuel requirements. Ten references are given covering the development of this method. G. K. A.

1923. Patents. M. S. Kharasch, assr to United States of America. U.S.P. 2,504,134, 18.4.50. Deleading of gasoline by adding perhydrohalide and then treating the mixture with charcoal.

C. H. Van Hartesveldt, assr to Thompson Products Co. Inc. U.S.P. 2,504,361, 18.4.50. Anti-detonant fuel adapted for periodic introduction into a main hydrocarbon power fuel–air mixture made up of 3–6 cc of T.E.L/gal of supplementary fuel, and an aqueous solution of not less than 73·5% by volume methanol and the balance water.

M. P. Kleinholz, assr to Sinclair Refining Co. U.S.P. 2,506,089, 2.5.50. A diesel fuel consisting of hydrocarbon diesel oil blended with a cetane-improving quantity of a polyolefin.

H. Boardman, assr to Carboline Ltd. U.S.P. 2,506,539, 2.5.50. An improved fuel for I.C. spark-ignition engines comprising from 0·001–0·03% by weight of a mixture of an aromatic metal-free nitro compound and an iron salt of an aromatic nitro acid. C. F. S.

Gas Oil and Fuel Oil.

1924. Erosion and corrosion damage from use of heavy oils as engine, boiler and turbine fuels. B. Engel. *Erdöl u. Kohle*, 1950, **3**, 321–7.—Erosion can be due to sand, ash, and cavitation; first two causes can be largely diminished by centrifugal purification of the fuel. Main causes of corrosion are S oxides, products of incomplete combustion, and presence of V and alkaline earths in the ash. Published work on ash reduction of fuel oils is reviewed, with particular reference to that of Lamb (*J. Inst. Petrol.*, 1949, **35**, 405). Tests were made on reduction of V content of fuels from Venezuelan and Middle East crudes. V is present in oil-sol form, and whilst reduction of V content by chemical and physical means was small, some success was achieved by addition of materials (As, chlorinated hydrocarbons) which inactivate the V present. Corrosion can be caused by attack, on metal and refractories, of C and H formed by cracking reactions. Reactions such as $CO_2 + SO_2 \rightleftharpoons CO + SO_3$ can also be harmful. C formed by incomplete combustion of inadequately atomized fuels can be detrimental to surface of metal and of furnace linings; hence excess air is preferable to insufficient air. Refractory ceramics should contain $< 40\%$ Al_2O_3. V. B.

1925. Ejection of heavy liquid fuel during its combustion from a free surface. G. N. Khudyakov. *Izvest. Akad. Nauk S.S.S.R., Otdel, Tekh. Nauk*, 1950, 682–8.—Laboratory experiments were made on burning of pet oils, floating on water, in a quartz vessel 71 mm dia and 200 mm high. Heat reflected from flame travels down through oil, and gradually heats up latter. Temp of surface layer of burning liquid varies from 78° C (light gasoline) to 502° C (dry heavy fuel oil). Light oils (up to kerosine) burn smoothly, but heavier oils either boil over or else are violently ejected from the combustion vessel. Boiling over usually occurs when fuel contains emulsified water. Wet oils heat up more rapidly than dry, due to better thermal conductivity. Max possible foam formation in wet oils is approx 20 l foam/kg oil for every % of water content. Boiling-over of burning fuel is frequently accompanied by flame-extinction. Mechanism of violent ejection, due to formation of steam pocket at oil/water interface, is discussed. Rising steam bubbles displace hot surface oil to bottom of oil layer, where, at oil/water interface, it causes rapid vaporization of water, resulting in explosive ejection of burning oil from the container. V. B.

Lubricants.

1926. Friction and wear tests in lubrication. R. Halder. *Erdöl u. Kohle*, 1950, **3**, 222–6.—Three lubricants of different types, a hydrocarbon oil, rape oil, and a S-containing E.P. additive, having visc (cs) at 38° C of 36·2, 47·8, and 22·4 respectively were tested in five apparatuses (two specially constructed wear testers and four-ball, Falex, and Almend-Wieland friction testers). Test conditions are tabulated. In wear test soft iron rod (against roughened hardened steel) showed much more wear, both at 40° and 85° C, with rape than with other two lubricants. Additive causes much greater wear on hardened than on unhardened member of wear-test pair. Rape gives good performance in Almen-Wieland and Falex testers, whilst additive has best showing in normal four-ball test. If, however, in latter hardness of steel balls is lowered or iron balls are used test results are markedly influenced, leading even to reversal of order in which lubricants are placed. Test results indicate that lubricants can be properly assessed only with reference to conditions in which they are to operate and particularly metals on which they are used. Lubricants must be tested to limit of their load-bearing capacity in order to obtain proper evaluation, *e.g.*, E.P. oils behave unfavourably at low mechanical and thermal loads, but show up to advantage under conditions at which a hydrocarbon oil fails. V. B.

1927. The performance of crankcase lubricating oil. A. Towle. *Petrol. Times*, 30.6.50, **54** (1380), Supp. 4 pp.—The many factors that affect the performance of lubricants in crankcase service are reviewed on general lines. Attention is given to the influence of diesel and gasoline fuels, of operating conditions, and of the mechanical condition of the engine.

Laboratory engine tests, with particular reference to the use of the Petters AVI single-cyl unit, are described, as are the methods of evaluating oils by these tests. In considering costs from the point of view of the oil user, the author contends that the cost of the oil cannot be divorced from the cost of maintenance, and that the only factor with any meaning is that obtained by adding the cost of the lubricating oil to the cost of overhauling the engine, and then dividing by the mileage covered between overhauls. Evidence is presented to show that the saving by use of better-quality oils is reflected in extended periods between overhauls, and that to take full advantage of this saving no attempt should be made to extend the period between oil drains. J. H. P.

1928. Lubricant research in the laboratory. N. Lamme. *Ingenieur*, 19.5.50, **62** (20), Mk. 48.—The author deals with the various tests on which are based the specification of a lubricating oil, indicates the interpretation to be placed on the figures obtained, and demonstrates how they can be translated into terms of performance to be expected, and the suitability of the oil under test for any specific purpose.

In the evaluation of eight oils on which tests have been carried out, the following properties have been determined: ring analyses, average mol wt, and acid and saponification values after ageing. From an examination of the figures obtained, the eight oils under consideration are catalogued as to their general properties and the

types of internal-combustion engine in which they could best be used. These conclusions are compared with the results actually obtained on engine test.

A short reference on similar lines is also made with regard to the examination of lubricating greases. R. R.

1929. Turbo-alternator lubricating systems. Anon. *Mech. World*, 14.7.50, **128** (3313), 40.—During past forty years power-station generating sets have increased in capacity and speeds, and in view of the higher speeds the lubricating systems have become of very great importance. The oil used should be continuous, cool, free from injurious matter, and maintained under pressure. Cleanliness should be aimed at in all parts of the set. Application of paint to bearing castings, tank interiors, pedestals, etc., should be avoided whenever possible as it can do more harm than good. Methods of cleaning the oil system are described, and a number of recommendations given whereby the lubricating system can be maintained efficiently. A. S.

1930. Manufacture of lubricating greases. IV. Aluminium and barium-base greases. C. J. Boner. *Refiner*, June 1949, **28** (6), 127–30.—Aluminium-base greases are manufactured because the product, though expensive compared with calcium or sodium-base greases, is usually clear and of attractive appearance. Barium-base greases are water and heat resistant. Batch and continuous manufacturing processes are described. W. E. M.

1931. Lubricating oil additives. 2. Viscosity index improvers. V. A. Kalichevsky. *Refiner*, July 1949, **28** (7), 125–8.—The performance of V.I. improvers depends mainly upon the nature of the oil. A comprehensive list of patents is given, but many are unsatisfactory because of unfavourable effects upon other properties of the oil. W. E. M.

1932. Lithium base and miscellaneous lubricating greases. C. J. Boner. *Refiner*, July 1949, **28** (7), 129–33.—Lithium-base greases are especially adaptable for use as low-temp aircraft lubricants. Care must be taken in the choice of fatty acids, mineral oil, and manufacturing procedure for a stable grease. Batch and continuous processes are described. The manufacture of strontium-base greases is also described. These are particularly stable and suitable for work at high temp.

The following are also briefly described, lead-, zinc-, and magnesium-base greases, inorganic fillers, organic fillers, synthetic diluents, silcone grease, polyalkylene glycols, esters, and fluo-lubes. W. E. M.

1933. Patents. B. B. Farrington and F. A. Leyda, assrs to California Research Corpn. U.S.P. 2,504,672, 18.4.50. A lubricating grease comprising mineral lubricating oil, lithium soap, and zinc dialkyl dithiocarbamate.

H. G. Smith, T. L. Cantrell, and J. G. Peters, assrs to Gulf Oil Corpn. U.S.P. 2,504,742, 18.4.50. Antioxidants for mineral oil lubricants are prepared by heating 1–4 mols of monohydric phenol, 1–4 mols of *N*-dimethylaniline, and 0·5–4 mols formaldehyde per mol of phenol in the presence of actived clay catalyst.

H. G. Smith, T. L. Cantrell, and J. G. Peters, assrs to Gulf Oil Corpn. U.S.P. 2,504,743, 18.4.50. Antioxidants for mineral lubricating oils are prepared by heating *p*-hydroxydiphenyl with from 4–9 mols of *n*-dimethylaniline and 4–9 mols formaldehyde per mol of *p*-hydroxydiphenyl in the presence of activated clay catalysts.

D. W. Young and W. H. Smyers, assrs to Standard Oil Development Co. U.S.P. 2,504,779, 18.4.50. A lubricating grease made up of 67–94% by weight of lubricating oil, 5–30% of a thickener, and 1–3% of a "cycalkene" copolymer containing between 40 and 65% by weight of a cyclic constituent, and an intrinsic visc above 0·5.

A. W. Weitkamp and J. C. Stamm, assrs to Standard Oil Co., Indiana. U.S.P. 2,505,222, 25.4.50. The preparation of a rosin soap grease by heating a mixture of hydrocarbon oil, rosin, and a modified rosin, hydrogenated rosin, from about 150–300° F, and saponifying with an alkali metal and alkaline earth base saponifying agent.

G. R. Waitkins, assr to Battelle Memorial Institute. U.S.P. 2,506,049, 2.5.50. A lubricant comprising a mineral oil and a small amount of an oxidation inhibitor selected from the group of alkyl, alkaryl, aralkyl, and aryl selenonophosphates.

L. A. Mikeska, assr to Standard Oil Development Co. U.S.P. 2,506,310, 2.5.50. A lubricating oil composition containing about 0·02–3% of a metal salt of an organo-substituted thiophosphoric acid, obtained by reacting phosphorous pentasulphide with a mixture of wax-phenol and an aliphatic alcohol.

H. J. Andress, assr to Socony-Vacuum Oil Co. Inc. U.S.P. 2,506,570, 9.5.50. Lubricating oil comprising a mineral oil fraction and an oxidation inhibitor of acidic, phosphorous-, and sulphur-containing reaction product of a wax-substituted phenol.

J. D. Bartleson, assr to Standard Oil Co. Ohio. U.S.P. 2,506,572, 9.5.50. A mineral lubricating oil containing an additive to inhibit corrosion, lacquer and sludge formation, the additive being the reaction product of 0·5 mols–2·5 mols of a phosphorous sulphide and 1 mol of a saturated amine.

J. D. Bartleson, assr to Standard Oil Co. Ohio. U.S.P. 2,506,573, 9.5.50. A lubricant comprising an oil dispersible reaction product of 1 mol of an unsaturated organic amine and 0·3–2·5 mols of a phosphorous sulphide reacted at an elevated temp, which contains an added element of the sulphur family reacted therein at a temp in the range of 200–300° F. C. F. S.

Bitumen, Asphalt, and Tar.

1934. Design of seal coats and surface treatments. F. N. Hveem, W. R. Lovering, and G. B. Sherman. *Rds and Streets*, Apr. 1950, **93** (4), 91.—Seal coats are applied to roads to accomplish one or more distinct purposes. These purposes are in approx order of importance as follows :—

1. To seal the road against the entry of moisture or air.
2. To develop a non-skid texture.
3. To apply a fresh coat of bitumen which will enliven an existing surface and thus improve wear resistance.
4. To reinforce an inadequate pavement section.
5. To provide a demarcation for traffic guidance.
6. To improve luminosity at night.

Seal coats generally consist (at least in California) of one application each of bitumen and chippings. The following factors must be borne in mind before applying a seal coat :—

1. Quality of chippings.
2. Quantity of chippings.
3. Selection and application of binder.
4. Weather conditions.

These factors are explored in detail with the appropriate recommendations.

R. H.

1935. Bituminous flexible pavements—design considerations and construction practice in Wisconsin. A. T. Bleck. *Rds and Streets*, May 1950, **93** (5), 74.—The condition of a pavement foundation depends to a large extent upon its actual water content and also upon its potential water content. Thus the movement of moisture in a soil is important, the prevalent theory being that "capillarity" is responsible for this movement. Experience has shown that pavements lying upon soils with high capillarity properties seldom, if ever, exhibit distress in the summer-time. The complete theory of moisture movement with particular reference to the work of Stephen Taber is described. The prevalent conditions in Wisconsin are explained, and details of work carried out there given. R. H.

1936. Patent. V. R. Smith and C. G. Schmitz, assrs to California Research Corporation. U.S.P. 2,506,283, 2.5.50. Preparation of air-blown polymerized asphalt containing a residue of polymerization-promoting metallic salts, to which is added a

material from the group consisting of calcium and magnesium oxides and hydroxides, to prevent scumming and hardening by the salts. C. F. S.

Special Hydrocarbon Products.

1937. Trimethylbenzyl chlorides and their derivatives: preparation from aromatic petroleum stocks. H. D. Hartough. *Industr. Engng Chem.*, 1950, **42** (5), 903–8.—Chloromethylation has been studied for separation of xylenes and trimethylbenzenes in aromatic petroleum stocks containing also paraffins and naphthenes. The present work describes isolation of trimethylbenzene chlorides from such stocks, and includes a study of variables such as mol ratio of HCHO to aromatics, reaction time, agitation, and use of HCl. Separation and identification of isomeric trimethylbenzene chlorides are discussed and their chemical properties briefly listed. Various derivatives of the chlorides were prepared—alcohols, ethers, and dichloromethyl compounds.

R. G. T.

1938. Patents. F. H. MacLaren and J. A. Anderson, assrs to Standard Oil Co., Indiana. U.S.P. 2,504,270, 18.4.50. Wax composition comprising milling an ethylene polymer and from 5 to 60% by weight of a petroleum wax at a temp from 220° to 360° F, then dissolving the blend in petroleum wax at a temp of from about 140° F to about 250° F to get a complete solution of the ethylene polymer in the petroleum wax.

M. Erchak, assr to Allied Chemical and Dye Corpn. U.S.P. 2,504,400, 18.4.50. Production of high-melting waxes from ethylene by maintaining ethylene under pressures between about 425 and 475 atm, and temp 140° and 200° C in contact with *iso*propanol, and containing from about 0·1–2% by weight on the *iso*propanol of hydrogen peroxide on a 100% hydrogen peroxide basis.

J. R. Bowman and W. P. Ridenour, assrs to Gulf Research and Development Co. U.S.P. 2,506,059, 2.5.50. A solid paraffin wax composition, consisting of paraffin wax and from about 0·1–0·5% aluminium stearate. C. F. S.

Derived Chemical Products.

1939. Sulphur compounds from petroleum compounds. Reactions and derivatives of tertiary aliphatic mercaptans. W. A. Schulze, G. H. Short, and W. W. Crouch. *Industr. Engng Chem.*, 1950, **42** (5), 916–21. (*Chemicals from Pet. Symposium. 5th S. West Mtg. Amer. Chem. Soc. Okla.*, Dec. 1949.)—Research and development are described in the preparation, properties, and uses of derivatives readily obtainable from tertiary aliphatic mercaptans. Reactions of mercaptans with O_2, S, CS_2 + NaOH, Cl_2 (with secondary reaction of the sulphenyl chlorides to dithiocarbamates, sulphenamides, sulphenyl xanthates), ethylene oxide, aldehydes, PCl_3, and metal salts. Products include aliphatic disulphides, polysulphides, trithiocarbonates, mercapto polyether alcohols, mercaptals, phosphorus thio esters, and metal mercaptides. Commercial development is cited in some cases, and industrial applications are described: lubricant additives, ore-flotation collectors, vulcanization accelerators, fungicides, and non-ionic detergents. R. G. T.

1940. Patents. R. C. Morris, J. L. Van Winkle, assrs to Shell Development Co. U.S.P. 2,504,098, 18.4.50. Asymmetrical sulpholanyl ethers of heterocyclic alcohols of the general formula X–O–Y, where X is member of group of oxa*cyclo*pentylcarbinyl containing from one to two oxygen atoms, and Y a radical of the group of sulpholanyl and sulpholenyl radical.

R. C. Morris, J. L. Van Winkle, assrs to Shell Development Co. U.S.P. 2,504,099, 18.4.50. *Cyclo*hexyl ethers of cyclic sulphones of the general formula X–O–Y, where X is polyalkyl-substituted *cyclo*hexyl and Y is a radical of the group of sulpholanyl and sulpholenyl radical.

C. J. Plank, D. E. Badertscher, assrs to Socony-Vacuum Oil Co. Inc. U.S.P. 2,504,100, 18.4.50. Production of phenol aldehyde resins by condensing phenol and

formaldehyde in molar proportions of 6 : 7 in the presence of boron trifluoride at temp of 0–182° C.

R. Rosen and E. Arundale, assrs to Standard Oil Development Co. U.S.P. 2,504,732, 18.4.50. The preparation of meta-dioxanes by condensing formaldehyde with propylene in the ratio 1·5 : 1 mol, in the presence of an aqueous boron fluoride catalyst.

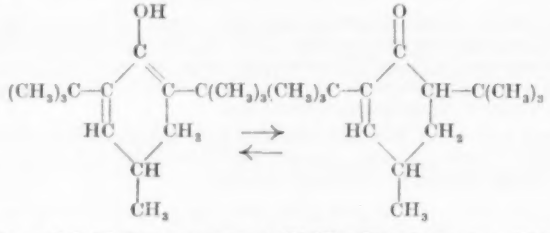
S. J. Hetzel, assr to Sun Oil Co. U.S.P. 2,504,929, 18.4.50. A composition comprising a polyvinyl chloride resin plasticized with 1 : 5-pentanediol-bis-*cyclo*hexyl-acetate.

S. J. Hetzel, assr to Sun Oil Co. U.S.P. 2,504,930, 18.4.50. A composition comprising a polyvinyl chloride resin plasticized with 1 : 5-pentanediol difuroate.

E. C. Pitzer, assr to Standard Oil Co., Indiana. U.S.P. 2,504,204, 25.4.50. A copolymer of a vinylthiophene and a diolefinic compound, containing at least 5% but not more than 90% of a vinylthiophene.

A. C. Whitaker and W. W. Weinrich, assrs to Gulf Research and Development Co. U.S.P. 2,505,816, 2.5.50. As a new product the compound 4 : 6-di-tertiary-butyl-2-methyl*cyclo*hexanone.

A. C. Whitaker and W. W. Weinrich, assrs to Gulf Research and Development Co. U.S.P. 2,505,817, 2.5.50. An equilibrium mixture of enol and keto form of compounds having the formulas :—



H. R. Snyder and J. M. Stewart, assrs to Phillips Petroleum Co. U.S.P. 2,505,870, 2.5.50. The production of secondary and tertiary alkylthiol amines. C. F. S.

Coal, Shale, and Peat.

1941. Liquid fuels from coal and oil shale. G. Roberts and P. R. Schultz. *Refiner*, 1950, **29** (1) 104–8.—The costs of producing liquid fuels from natural gas, oil shale, bituminous and sub-bituminous coals are compared with that of a Wyoming Crude. The Union Oil Company's type of upflow retort was used as a basis for the oil-shale study, and the Fischer–Tropsch process for the gas and coal. Economically, as yet, liquid fuels from oil shale and coal cannot compete with those derived from crude, however, further research and development may improve the position. The use of natural gas as a raw material will depend on the relative locations of source and market. R. W. G.

1942. Production of detoxified grid gas by pressure gasification and synthesis with iron catalysts. H. W. Gross. *Erdöl u. Kohle*, 1950, **3**, 218–22.—Removal of CO from coal gas by passage over Fischer–Tropsch cat yields valuable hydrocarbons, thus reducing net cost of gas as well as detoxifying it. It is, however, necessary to avoid undue changes in cal. val. and burning properties of gas. CO content can be reduced to approx 1% by both Fe and Ni/Co cat, but former has less effect on other properties. Gas from pressure gasifiers must be specially purified before CO conversion so as to remove cat poisons such as resins. Products of CO conversion can be added to liquid-fuel fractions from pressure gasifier, thus increasing overall hydrocarbon fuel yield. Schematic diagrams of pressure gasification and gas-detoxifying processes are given, together with illustrations and some details of both pilot-plant and industrial installations. V. B.

1943. Thermodynamic study of coal gasification. Applicable to suspension gasification of pulverized coal. H. R. Batchelder and J. C. Sternberg. *Industr. Engng Chem.*, 1950, **42** (5), 877–82.—Continuous gasification of suspended powdered coal with superheated steam and oxygen has been studied thermodynamically. Equations for thermal balance and equilibrium are used in a method of calculation whose application for two coals at five O_2 : coal ratios is shown. The curves thus derived show effects of steam : coal ratio on product gas and on steam utilization and unreacted steam. These relationships show trends which can be used in determination of optimum operating conditions. R. G. T.

Miscellaneous Products.

1944. Petroleum-type hydrocarbons from sugar cane. H. Heinemann. *Refiner*, 1950, **29** (2), 111–14.—By using basically the same procedure as has been used for conversion of cellulose, potatoes, etc., cane sugar can be converted to hydrocarbons. An alkaline solution is heated to a temperature of 750° F. Bitumen, carbon dioxide, water, methane, acids, and coke are obtained. Vacuum distillation of the bitumen gives an asphalt closely resembling Trinidad asphalt. Hydrogenation of the bitumen followed by extraction and distillation yields gasoline, middle oil and lubricating oil fractions, and a residual asphalt fraction. By suitable treatment it is possible to convert about 33% of the dry cane sugar into petroleum-type hydrocarbons, 10% into gasoline, and about 7% into lubricating oils. R. W. G.

1945. Patent. E. D. Lee and R. J. Schefbauer, assrs to Interchemical Corpn. U.S.P. 2,505,866, 2.5.50. Printing ink comprising a solution of a resin in a petroleum hydrocarbon which is slow-drying at 20° C, but which volatilizes rapidly at 150° C, the resin being the fraction of Utah coal resin which is precipitated on dilution of a 25–45% solution in *iso*hexane to 10% concentration with *iso*hexane. C. F. S.

Corrosion.

1946. Design of cathodic protection for open-box-type coolers. C. R. Draughton and E. B. McNeil. *Oil Gas J.*, 1.6.50, **49** (4), 76.—Experimentation to prevent water-side corrosion in coil coolers by cathodic protection has been in progress for two years at Baton Rouge refinery of Esso Standard Oil Co.

Problems were current-density requirements and current distribution; it was estimated that a current of 6·6 mA/1 sq. ft. to surface to be protected was necessary.

Rectifier was a standard copper oxide oil-immersed unit rated at 15 V and 100 amps; the anode system consisted of 104 flat steel-plate anodes.

Current was drained from each vertical bank of tubes to a main-drain lead, which also drained the box wall.

As a result of twenty-one months' work, it is concluded that cathodic protection is an effective means of controlling corrosion, and it is economically justifiable. A current density of 10 mA/sq. ft. is recommended for water similar to that at Baton Rouge, a sufficient current density throughout the system being essential.

It is also concluded that the protection criterion used to determine degree of protection has not been definitely established.

Ten figures illustrate the article. G. A. C.

1947. Corrosion and protection of offshore drilling rigs. F. L. La Que. *Corrosion*, 1950, **6** (5), 161.—Summarized discussions given during panel on Corrosion and Protection of Offshore Drilling Rigs, Fifth Annual Conference, National Association of Corrosion Engineers, Cincinnati, Ohio, Apr. 11–14, 1949. J. T.

1948. Tubing corrosion. J. G. Yapuncich. *Oil Gas J.*, 6.4.50, **48** (48), 68.—A case is reported wherein despite a produced vol percentage of 35% H_2S, corrosion of well equipment is not prevalent. In one well, however, severe corrosion occurred. It appeared that corrosion was due to spent acid diluted with formation water remaining

in the well for a longer period than usual. The well history and description of corrosion are given. In order to determine relative corrosion rates and the nature of attack test specimens were subjected to acid solutions. Acid solutions used in the tests were raw 15% HCl; inhibited 15% HCl; acidic ember water (pH 2·5). Tests were made at room temp and at 180–215° F with specimens entirely immersed in the acid solutions. At the higher temps the inhibited acid and ember water were maintained at 180° F for 11 and 12 hr and then refluxed at their b.p. for the last period. Results indicated that at low temp inhibited acid and acidic ember water are relatively non-corrosive, whereas raw acid corrodes steadily. At the higher temp raw acid attacks without pitting, inhibited acid attacks by pitting, and general corrosion and acidic ember water only cause slight corrosion with shallow pitting. It was concluded that the corrosion encountered in the field could not be attributed directly to electrolytic action, action of acid, spent acid, formation waters, or carbon dioxide.

The corrosion was attributed to H_2S attack. Hydrogen sulphide is corrosive only in the presence of acidic waters and the presence of spent acid in the well, together with the high proportion of produced H_2S accounts for the severe corrosion. C. G. W.

1949. Installation and economics of placing magnesium anodes at leaks repaired on a pipeline. J. A. Holloway. *Corrosion*, 1950, **6** (5), 157.—When leaks are repaired magnesium electrodes can be easily installed to help the anodic areas of the pipe furnish current for the controlling cathodic areas. Leak-frequency records indicate that a reduced rate of corrosion can be obtained in this way until complete cathodic protection can be installed. J. T.

1950. Potentials set up by thermal gradients in iron immersed in NaCl solutions. H. H. Uhlig and O. F. Noss, Jr. *Corrosion*, 1950, **6** (5), 140.—The damage caused by galvanically coupling a piece of iron at high temp to another piece at low temp in an electrolyte is of practical importance, especially in industrial equipment such as condenser tubes, water-cooled radiators, boiler-tubes, stills, etc.

Laboratory experiments, with cells containing sodium chloride solutions in which seamless-steel tubing electrodes with one electrode at 100° C and the other at 25° C revealed that: (1) the potential of iron at 100° C versus iron at 25° C in 3% NaCl solution under specific conditions of aeration and stirring is 0·024 V with the hot electrode the anode; (2) decrease of aeration or stirring decreases the measured potential difference. In NaCl solutions more dilute than 3% the potential difference is also less; (3) the short-circuit current in aerated stirred 3% NaCl solution was 0·00043 am/sq. in., which is equivalent to an anodic corrosion rate of 0·03 inches per year. In nitrogen-saturated solution this current falls to zero; (4) the short-circuit current is apparently limited by the polarization of the cathode rather than the resistance of the electrolyte in the range 0·125–3% NaCl solutions. It appears that the iron electrode at 100° C as sacrificial anode, will cathodically protect iron at 25° C of equal area to which it is coupled in a 3% NaCl solution. J. T.

1951. Corrosive environments and methods of mitigation in producing sour crudes. D. A. Shock and J. D. Sudbury. *Oil Gas J.*, 8.6.50, **49** (5) 72; *Petrol. Engr*, June 1950, **22** (6), B-42.—Corrosive environments occurring in the production and handling of crude are classified as follows:—

(1) *Well environment.*—The presence of water, H_2S, CO_2, and fatty acids accounts for occurrence of corrosion. Factors affecting the rate of corrosion are: temp and pressure-effect solubility of gases in water and hence effect corrosivity. The oil–water ratio has some effect on corrosivity—high oil–water ratios being less corrosive. Velocity of produced fluids is important. The higher the velocity the greater the quantity of corrodent in contact with the surface and also the greater the erosion effect which tends to remove protective films. Embrittlement and blistering of metal by hydrogen produced by corrosive action may also be important.

Corrosion in such environment may be mitigated by: (*a*) alloys—generally too expensive; (*b*) coatings—varying considerably in performance; (*c*) inhibitors for the case of surface treating equipment where heat is applied to the crude, alloys have been found to be the best solution to severe corrosion problems.

Three other corrosive environments are treated in one section.

(2) *Water-zone environment.*—Corrosion may occur by H_2S or CO_2 attack and also by galvanic attack. If dissolved oxygen is present further corrodents may also be formed.

(3) *Oil-zone environment.*—This is the least corrosive environment. Corrosion is largely due to H_2S dissolved in water emulsified with the oil. Hydrogen blistering may be appreciable in this zone and the conditions leading to this require investigation.

(4) *Vapour environment.*—Corrosion is due to oxygen, water, hydrogen sulphide, and sulphur. Corrosion occurs on the dampened surface where droplets are present. Dissolved H_2S causes sulphide attack. Reaction of oxygen with dissolved H_2S produces sulphur. Direct oxidation of metal also occurs and reactions of oxides with H_2S and sulphur occur. Mitigation methods developed are :—

(1) *Coatings.*—Paints, plastics, galvanizing, and cement linings give varying degrees of protection. Zinc alloyed with small quantities of magnesium or aluminium gives better results than normal galvanized metals.

(2) *Alloys.*—Aluminium is resistant to vapour-phase corrosion but not to aqueous phase. Aluminium decks with a cone bottom and monel sump have proved satisfactory.

3. *Vapour-phase inhibitors.*—Addition of ammonia to the vapour phase has been found to reduce corrosion. The removal of oxygen from contact with the crude and, if possible the separation of the aqueous phase and neutralization of sulphide or other corrodent should be effective in preventing corrosion. References are appended.

C. G. W.

1952. A new method of measuring potentials of polarized electrodes in soil corrosion cells. W. Neighbours. *New Zealand J. Sci. Tech.*, Jan. 1949, **30** (4), 201.—A method is described whereby the current through a soil-corrosion cell can be interrupted and the potentials of the polarized electrodes during the interruption can be measured.

The current is measured by an electronic circuit, a diagram of which is given. The potential across the cell at interruption is balanced against a known potential, the null point being indicated by an oscilloscope.

Constructional details, wiring diagram, and photographs of the apparatus are given.

C. A. F.

1953. Patent. H. R. Moore. U.S.P. 2,505,785, 2.5.50. Method of producing a corrosion-inhibitive coating on ferrous metals by pretreating in an aqueous solution including : sodium dichromate in an amount of about 0·78% by weight of solution, phosphoric acid about 0·59%, reaction product of 29–90 mols ethylene oxide with 1 mol lauryl alcohol, about 0·002–0·2% by weight of solution—temp about 195–205° F, and withdrawing from solution after about 1–20 min. C. F. S.

Engines and Automotive Equipment.

1954. Pilot injection. Anon. *Auto Engr*, June 1950, **40** (528), 227.—Description given of equipment manufactured by C.A.V. Ltd., which is now being applied to high-speed passenger-transport engines. It provides a continuous injection, first part at a low rate lasting for the delay period, followed without interruption by second part at a higher rate. Quantity of fuel injected during the delay period is therefore kept at a min, while remainder completes combustion as rapidly as possible, but still under control and retaining full-cycle efficiency. Diagrams show pump-delivery valve, and injector nozzle, in which pressure at nozzle holes is maintained higher than cyl-gas pressure until final closure is made by seating of main nozzle valve, thus avoiding any possibility of fouling. Typical cyl pressure, injector-needle valve lift, and fuel-injection-rate diagrams, comparing pilot and normal injection, are included.

U. N.

1955. Marine gas-turbine research. Anon. *Motor Ship*, July 1950, **31** (366), 129.—Description and illustrations are given of Pametrada 3500-s.h.p. marine gas-turbine, which is now being tested. Testing can be carried out up to a power of 60,000 s.h.p., and dynamometer used has a speed, at max brake rating, of 160 r.p.m. Working

temps and pressures on the test bed are given for the turbine, which runs on diesel oil, although it is hoped later to burn heavy fuel. U. N.

1956. New gas turbine plant. Proposed combination of steam and gas power. Anon. *Motor Ship*, June 1950, **31** (365), 105.—The plan suggested for the installation of a gas turbine plant in an 18,000-ton tanker by the A/B De Lavals Angturbin, Stockholm, and Eriksbergs Mek. Verk. was described in *Motor Ship*, June 1948. The combination of steam- and gas-power instead of the straight gas-turbine drive should give a higher efficiency and assured reliability, the steam-plant remaining in operation if the turbine fails. The geared steam-turbine and the gas-turbine each develop about equal power, the gas-turbine providing the hot gases supplied to the boiler. The turbine includes high-pressure and low-pressure independent units, as well as an astern turbine, and if the gas-turbine is out of action the boiler is oil-fired. The general lay-out of the plant is illustrated. U. N.

1957. 500 h.p. diesel mechanical locomotive. Anon. *Mech. World*, 7.7.50, **128** (3312), 18.—A diesel-mechanical 0-6-0 locomotive has been recently constructed in the Southern Region works at Ashford. It is powered by a Paxman 12 RPH V-type engine developing 500 b.h.p. at 1250 r.p.m. which has a bore of 7 in and a stroke of 7¾ in, the cyls being arranged in two banks of six at an included angle of 60°. Each bank consists of two castings of three bores, and the engine incorporates the Ricardo combustion system permitting low injection pressures, and the use of a single-hole pintle-valve injector. The drive is taken through a size 29 Vulcan-Sinclair scoop-control fluid coupling and an S.S.S. Powerflow gearbox, giving three forward and reverse gears in either high or low range. This provides a wide operating range from 5 m.p.h. in first gear low range to 36 m.p.h. in third gear high range. A cooler is provided for the fluid coupling, fed from the engine cooling system, to cater for high slip conditions at low rail speed, and with close adjustment of the engine speed gives a suitable range of speed for hump shunting. On down grades, by moving the gear lever into "coast" position the engine is disconnected from the gearbox. This operation withdraws the scoop tube and reduces the engine speed to idling. Various other design features are described and discussed. A. S.

1958. Radioactive tracers used in research on engine wear. P. L. Pinotti, D. E. Hull, and E. J. McLaughlin. *Petrol. Engr*, June 1949, **21** (6), C-5.—Using radioactive piston-rings the wear was determined by the change in the radioactivity of the oil. The rings were standard cast-iron rings and were made radioactive by irradiation in a pile and had a half-life of about fifty days. Results show that the wear ratio is high during the start break-in, stops gradually, and levels out at a constant rate at the end of 2-hr operation. Increased operating jacket temp decreased the wear, while decreased load output also decreased the wear. Superior oils showed a marked decrease of wear, and the effect of sulphur was shown by an increase of wear with increasing sulphur content. The results of six reference tests showed the excellent reproducibility of the method. G. K. A.

1959. Piston velocities and piston work. The influence of high piston velocities on the pressure distribution and piston work in engine cylinders. J. S. Glass and J. Kestin. *Aire. Engng*, June 1950, **22** (256), 163.—The thermodynamic processes in an engine cyl are analysed by applying the method of characteristics for solving problems of one-dimensional non-steady gas flows. To obtain an estimation of the influence of the finite piston velocity on the pressure distribution along a cyl as well as on the work done by the piston, ideal conditions of isentropic one-dimensional flow are assumed, excluding the influence of friction, exchange of heat, and turbulence. State and position diagrams have been constructed, and are shown for two examples, with assumed data corresponding to the standard air-cycle of a Hillman 10-h.p. engine. From these examples the conclusion is drawn that although the assumption that the processes of compression or expansion are quasi-static is not strictly true, the difference in the work is negligible, even in the case of the highest piston velocities met in practice. The pressure distribution along the cyl axis is nearly uniform. Differences become tangible only at exceedingly high piston velocities, which are, in fact, unattainable. Seven literature references are included. U. N.

1960. Patents. K. V. Anderson, assr to Nordberg Manufacturing Co. U.S.P. 2,504,243, 18.4.50. A method of control for I.C. engines which comprises sensing the temperature of exhaust gases discharging from the engine and varying the rate of combustion air flow in direct relation thereto.

W. E. W. Nicolls, assr to C.A.V. Ltd., England. U.S.P. 2,506,235, 2.5.50. Reciprocatory pump for supplying liquid fuel to I.C. engines. C. F. S.

Safety Precautions.

1961. Earthing of electrical plant. Anon. *Mech. World*, 14.7.50, **128** (3313), 43.—A higher-voltage system is earthed chiefly for the protection it affords to the system, whereas a lower-voltage neutral is earthed to reduce possible danger to human life. The regulations require that where electrical energy is transformed, the lower-voltage system should be prevented from becoming charged above its normal voltage by way of leakage or electrostatic induction from the higher-voltage system. The paper consists of a summary of earthing practice in relation to requirements of regulations. A. S.

1962. Life and death in an oil refinery. Part 4. P. M. van Arsdell. *Petrol. Engr*, Sept. 1949, **21** (10), C-16.—In hydroforming the alumina molybdena catalyst has weak toxicity, but the aromatics formed in the process are a source of danger. Benzene is the most toxic, toluene, xylene, and cumene having similar effects. Benzene is a cumulative poison which in its acute phases acts on the nerve centres, while chronically it affects the blood; fat emboli formed block the capillaries, white blood cells decrease due to attack on bone marrow, and anæmia sets in. Benzene is absorbed through the skin, and should be washed off immediately. Workers should have frequent blood counts and urinalyses. Polymerization and isomerization have the same hazards as distillation, together with the danger from aluminium chloride and HCl. Both are strong irritants of the skin and mucous membrane. Aluminium chloride on the skin should be wiped off first, and then thoroughly washed off. Initial washing may cause burns from the heat of solution. In dehydrogenation there is danger from inhalation of dust containing chromium, this should never exceed 0·1 mg per cu. m. Alkylation has the hazards of sulphuric acid and HF. Both cause severe burns and HF is violently toxic. Chronic effect is on the bone structure. HF burns should be treated with magnesium oxide paste to absorb the F ions G. K. A.

1963. Life and death in an oil refinery. Part 5. P. M. van Arsdell. *Petrol. Engr*, Nov. 1949, **21** (12), C-17.—Gasoline finishing plant hazards are considered. Ethanolamines are drying and have defatting action on the skin. Copper chloride dust is dangerous, and protective coverings should be used. The dust is caustic in contact with mucous membrane, ingestion leaves metallic taste, constriction of the throat, and griping pains in the abdomen. First aid is to give an emetic. Alkylphenols are caustic, systematic signs due to absorption by the body are warty growths, pigmentation on the skin and poisoning of the blood. Caustic soda is so universally used that people tend to be careless in its handling. Caustic burns are very deep-seated, and the action of dust in the eyes is so rapid that vision is usually lost. Doctors should be consulted over deep-seated burns and immediately there is any chance of eye injury. Methanol has paralysing effect on the central nervous system and a toxic action due to the methyl radical. The body has great difficulty in destroying methyl alcohol. Methanol has a specific effect on the optic nerve giving blindness. In all cases of inhalation a physician should be consulted without delay. Gum inhibitors have a caustic effect. Absorption of tetraethyl lead has serious consequences as is generally realized. An extensive bibliography is given. G. K. A.

1964. Mixing leaded gasolines. L. R. Fleck. *Refiner*, July 1949, **28** (7), 139–42.—A comprehensive programme for the safe handling of lead tetraethyl has been developed. Experience has shown that mixing plants should be located at least 50 ft from other buildings and at least 100 ft from processing equipment, storage tanks, etc. If the plant is supplied by rail, the ideal arrangement is a dead-end spur track equipped with

bumpers and de-rail. Elsewhere the car should be protected from collision and accidental removal.

Suggested types of tanks and drums for the transport of lead tetraethyl are described. T.E.L. should be transferred under partial vacuum. The design and efficient use of suitable eductors are described. Routine operations for blending T.E.L. with gasoline are given for various types of installation. W. E. M.

MISCELLANEOUS.

1965. Can world petroleum production be predicted? G. Brennich. *Erdöl u. Kohle*, 1950, **3**, 231–3.—Rate of increase of pet production in 1907–40 was greater than that of any other major industrial material except bauxite and alloy metals for steel. Applying technique of probability calculations to petroleum-production statistics it is concluded that rate of increase is now changing from a geometric to an arithmetic progession. Point at which production curve may be expected to take a downward trend appears to be too far in future for estimate to be made; a steady rate of production increase is forecast for next 10–20 years. V. B.

1966. Profits seconds largest in history. H. E. Rose. *World Petrol.*, 1950, **21** (6), 30–3.—1949 finances of twenty-six U.S. oil companies are tabulated. Earnings fell 26·7% on 1948 figures, capital expenditure was cut, and dividends increased. E. B.

1967. Refining trends for March, 1950. Anon. *Petrol. Process.*, 1950, **5** (4), 415–17.—The trends in stocks and demands during March 1950 in the U.S.A. are illustrated and compared graphically with similar data over the last two years for motor fuels, heating oils, residual, and natural-gas liquids. A peak demand for distillate heating fuels was experienced during March, whilst the demand for residual oils dropped. Forecast stocks and demands for the rest of 1950 are also indicated. D. W. F.

1968. Liquefied petroleum gas sales continue to gain. K. W. Rugh and E. D. Mattocks. *Refiner*, 1950, **29** (2), 133–4.—It is estimated that total vol marketed in the U.S.A. during 1949 was 2725 million gal. This represents an 8·5% increase over 1948 figures. 1650 million gal were used by domestic consumers and the rest for industrial purposes, I. C. operation, gas manufacturing, chemical industry, etc. A table shows annual distribution since 1922. R. W. G.

1969. Outlook for gas liquids industry. D. P. Thorton. *Petrol. Process.*, 1950, **5** (4), 373–6.—The long-term expansion of natural-gas and cycle-plant industries in the southwestern states of N. America is viewed with respect to economic and market factors. Recently installed natural-gas liquid plants have resulted in greatly increased production and subsequent price depression. Tables are included showing: (1) natural-gas production and utilization in southwestern states for 1949; (2) production over 1945–49 of finished gasoline from natural gas; (3) product volume from Texas cycling plants in 1949; (4) estimated southwestern field production in 1950 of natural gas and liquified petroleum gas. Future cycle plants may be equipped to make finished motor fuel by reforming, etc. It is believed that 1950 plant designs will favour high butane recovery at the expense of lower propane recovery. D. W. F.

1970. Trends in the design of new plants for recovering liquid from gas. C. F. Sanderson and A. S. Glendening. *Petrol. Process.*, 1950, **5** (4), 377–83.—A few of the plants constructed during the past eighteen months are discussed. Interesting points elaborated upon are as follows:—

Plant sizes are still increasing. Steam heating of the oil stream is being replaced by furnace heating, giving a hotter circulating oil and steam-power for process pumps using high-pressure gas heated by the hot lean oil. Air cooling of units, used in arid districts, is only competitive with a good supply of cooling water for temps above 140° F. The extra cost of refrigeration for increased propane recovery is in some circumstances outweighed by other factors. Further propane recovery is not now so favoured as

previously, although a fractionating absorber has been installed in a plant for a propane recovery increase from 30 to 55%. Reduction of non-condensible vapours is carried out by rich-oil stabilization or a two-stage absorption-oil distillation. A liquid dessicant for obtaining a dew-point depression of about 90° F has been employed on one plant. D. W. F.

1971. Petroleum chemicals 1950 and 2000. G. Egloff. *Oil Gas J.*, 15.6.50, **49** (6), 99.—The petrochemical industry is reviewed and special reference made to the alcohol, agricultural chemicals, synthetic rubbers, plastics, chemicals for synthetic textiles, fibres, detergents, aromatics, and miscellaneous products sections in the U.S.A.

Investment in petrochemical plants is expanding rapidly.

A table shows weight of chemical products partly from petroleum in 1950, and estimated weight for 2000. G. A. C.

1972. Hydrocarbon oils and the 1950 Finance Bill. Anon. *Petrol. Times*, 14.7.50, **54** (1381), 499.—The relevant portions of the Finance Bill referring to hydrocarbon oils and power alcohol are noted, together with the new powers for the control of petrol substitutes. J. H. P.

1973. The concessions for petroleum exploration and exploitation in France. Anon. *Rev. Pétrolière*, May 1950 **22**, 15–27.—The texts of the various permits for the search and exploitation of petroleum in France are given in some detail. J. T.

1974. Gulf coast's petrochem plants : their locations and products. Anon. *Oil Gas J.*, 22.6.50, **49** (7), 301.—Petrochemical and associated chemical plants and their products, located on the Gulf Coast from Lake Charles, La. to Brownsville, Texas, and inland 100 miles from the coast, are listed.

Value of plants listed is estimated at $700 million, and total production of finished petrochemicals for 1950 is estimated to reach 12,000,000,000 lb, nearly 2½ times 1949, output. G. A. C.

1975. Oil progress in Yugoslavia. E. A. Bell. *World Petrol.*, 1950, **21** (6), 44, 46, 59.—Review is given of exploration and development activities, largely based on official reports from Belgrade. Home production of drilling equipment supplements foreign purchases. News of refinery expansion and production is incomplete, but finished products are still being imported. E. B.

1976. "Mighty Antar" oil—field tractors and trailers. Anon. *Engineer*, 1950, **189**, 498–501 ; 542–4 ; 568–9 ; 611–12.—Thirty-five tractors and pipe-carrying semi-trailers, together with one low-loading semi-trailer have been ordered by Iraq Petroleum Co. for transport and stringing of 560 miles of pipe from Kirkuk to Banias on Eastern Mediterranean coast. The Thornycroft tractors of 250 h.p. are largest ever built in Great Britain, and are specifically for oilfield or civil-engineering work. They are powered by Rover "Meteorite" V-8 diesel engines, and are suitable for gross train weight of up to 100 tons. Engine cylinder blocks are of cast aluminium alloy. Each cyl has two inlets and one exhaust valve, sodium cooled, and tipped with Stellite. Cyl liners are Cr plated at top ends. Duplex scavenge oil-pump is used on lubrication system. Water-cooling is by twin radiators with close-tip-clearance fans. Engine-oil cooling is by air over a bank of horizontal tubes in front of one radiator. Gearbox gives twelve forward and three reverse speeds, max speed being 28 m.p.h. Flywheel, clutch, and gearbox unit is mounted separately from engine, clutch housing being cooled by a fan. Drive is taken to both sets of rear wheels (eight tyres), final drive gearing comprising worm primary reduction and epicyclic secondary reduction, giving full differential action. Springing is arranged so that upper leaves only come into action after a certain amount of initial deflection has occurred. Diagonally opposite wheels in the rear bogie can simultaneously have a 15-in difference in level. Steering is power-assisted. Braking is by compressed air, the compressor being driven by a power take-off at the gearbox. Pipe-carrying semi-trailer bogie can be carried on the tractor bogie when not loaded, or towed by the draw-bar. When loaded with seven 93-ft pipes latter act as connecting link between tractor and semi-trailer. The low-loading machinery trailer has a de-

tachable swan-neck, and can be loaded either from front or side. Suspension of the trailer wheels is by two beams bushed so as to rock freely, which design has proved very successful over rough ground. A. C.

1977. Calculation of laboratory cooling loads. C. P. Stolberg. *Heating and Ventilating*, June 1950, **47** (6), 69.—The determination of laboratory cooling loads, unlike laboratory building heat gain due to summer and outside temps and sun loads, is far from straightforward. In fact, it is a complex and difficult problem. A complete study must be made to determine the average number of people occupying each laboratory unit during an average working day. To obtain the internal heat gain due to laboratory equipment it is necessary to take into account not only permanently installed laboratory equipment such as ovens, baths, hot plates, and motors, but also portable equipment such as bunsen burners, mantles, small furnaces, etc. However, the biggest difficulty is to determine the probability of use of each piece of equipment, *i.e.*, the load factor. An example of laboratory load calculation is presented. A. S.

1978. Magnetic-particle inspection—applications in the petroleum industry. W. E. Thomas. *Oil Gas J.*, 8.6.50, **49** (5), 53.—This non-destructive method, applicable only to detection of flaws in materials such as iron and steel, and iron alloys, which can be magnetized depends on the fact that if a crack or crack-like discontinuity is transverse to the direction of the magnetic field in the material, the field is distorted and flux lines are crowded or deflected around ends of such a magnetic obstruction.

For location of discontinuities below the surface, the continuous direct-current method is the best, but alternating current is as effective for detection of surface cracks or discontinuities very close to the surface.

Method is of use in detecting fatigue in metal equipment subject to repeated stresses, and injection of welds to obviate pipe failures. G. A. C.

1979. Use of deep-sounding in the determination of pile bearing capacity safety factors. C. van der Veen. *Ingenieur*, 25.6.50, **62** (25), B-67.—About 1935 the deep-sounding method was developed in the Netherlands as a way to predetermine length and bearing capacity of piles. This method consists of pressing a cone of base area 10 sq. cm. (1·55 sq. in.) into the earth by way of a rod and measuring the soil's resistance to the entry of the cone. Friction between the rod and the soil is eliminated by having the former encased by a tube. Theoretical considerations and observations in the laboratory and field indicate that cone resistance per unit area may be assumed to be independent of the base area of the cone. It is possible therefore to calculate without difficulty the resistance offered to a pile tip if its base area be known. The safety factor is introduced in order to remain far enough from loss of equilbrium and not to exceed the admissible settlements of the foundation. Loading tests carried out on piles of different sizes show that a safety factor of 3 will normally be necessary, as opposed to the figure of 2–2½ which is often used.

The article is illustrated by a number of graphs which have been drawn on the basis of information obtained in the field. R. R.

1980. Submerged combustion and its application. E. F. M. van der Held and H. A. Leniger. *Ingenieur*, 30.6.50, **62** (26), CL.-35.—The paper discusses the mechanism of the process in detail, and includes a calculation for the time necessary for the cooling of gas bubbles of various diameters. Further, heat-transfer calculations are included, and two graphs and one table are provided by way of illustration.

A number of applications are quoted, among them being: the production of anhydrous Na_2SO_4, the recovery of KCl from alkaline waste, the concentration of $CaCl_2$, and the concentration of $MgCl_2$ from 16 to 34%.

The concluding section deals with the economics of the process. The use of double- or triple-effect evaporation, and of oil as fuel, are required to make the process attractive. Financial draw-backs and the limitations of the process to temperature-insensitive materials are indicated. R. R.

1981. Application of radioactive isotopes in the oil industry. K. Fearnside. *I.P. Review*, 1950, **4**, 173.—The present concept of nuclear physics is that the whole of the

mass of an atom is centred in the nucleus and that radiation proceeds from the nucleus as a result of natural or induced instability. The quantity of radiation can be measured by a Geiger counter or by an ionization chamber. This property can be applied to numerous industrial and chemical problems. In the petroleum industry the following applications are described :—

1. Oil production where radiation is absorbed by rock, but is scattered by the hydrogen atoms of the oil molecules and observed on a detector.
2. Flow in pipelines, where the progress of a new grade of oil pumped along the line is followed by observing radiation produced as a result of injecting radioactive material into the first portion of the new oil.
3. Removal of static electricity generated in pipelines when oil is pumped through. The pipe is lined with a suitable radioactive material which causes the charge to be dissipated.
4. Chemical problems and lubrication problems are investigated by the use of radioactive tracers. R. H.

1982. Environmental cancer and petroleum. S. J. M. Auld. *J. Inst. Petrol.*, 1950, **36**, 235–53.—The history of the earlier work done in recognizing carcinogenic materials is reviewed briefly. The oil industry has been concerned in the ætiology of skin cancer, first, as an occupational disease of paraffin-wax workers in the shale industry, of lubricating-oil users manifesting itself as mule-spinners' cancer and as an effect of exposure to cutting oils; secondly, experimentally as selective solvent extracts and in cracked oils of low volatility. The development of research in identifying non-carcinogenic oils for cotton spinning is described, together with the organization and objects of present research in this field. A. R. W. B.

1983. Wire rope usage—care, maintenance. A. J. King. *Petrol. Engr*, May 1950, **22** (5), B-62.—The development of rope is briefly reviewed. Modern wire rope consists of wire helically twisted into strands which are helically twisted round a core of fibrous or metallic material. The grades and construction of wire rope are described, and the advantages of preformed wire rope emphasized. Chief of these advantages are ease of handling and resistance to fatigue. Proper care of wire rope is emphasized. Damage may be caused by: (1) crushing, (2) kinking, (3) crosswinding, (4) overloads and shock loads.

Large-size drums should be used, and reversed bends, grooved drums, and misaligned drums should be avoided. Wire rope should be cleaned and lubricated, and changed end for end to distribute wear. Further factors and practices involved in making the best use of wire rope are described. C. G. W.

1984. Science lecture courses bring technical men up-to-date. A. L. Foster. *Petrol. Engr*, Sept. 1949, **21** (10), C-7.—Solutions of the problem of keeping technical men up to date in developments are for the men to do night study, to send them away, or to arrange courses on the spot. The Humble Oil and Refining Co. chose the last-mentioned course, and prominent men are invited to the main refinery to give lecture courses. Men are volunteers and are given time off to attend. Classes are limited to about sixteen, and the trainees are given an examination at the end. After working for three years the staff are enthusiastic over its aims and its results. A table of the courses offered and the status of the lecturers is given. G. K. A.

1985. Patent. L. Heard, assr to Standard Oil Co., Indiana. U.S.P. 2,505,895, 2.5.50. The preparation of gel catalysts by dispersing hydrosol stable for about a minute in droplet form in a coagulating bath until gelation, separating and drying to produce the catalyst. C. F. S.

BOOK REVIEW.

British Diesel Engine Catalogue (2nd Edn). Edited by D. S. D. Williams. London: Temple Press Ltd., 1950 (for British Internal Combustion Engine Manufacturers Association). Pp. xxxvi + 277. 54*s*. 6*d*.

About 90 per cent of the output of British oil-engine manufacturers is sold in markets outside the United Kingdom, and this catalogue is designed primarily to inform potential customers abroad of the complete range of engines available. A commendably aggressive sales policy is characterized by the statement in the foreword to the effect that although engines listed in the catalogue are, in accordance with modern convention, called "diesels," the assumption that Dr Diesel was the inventor of the modern compression-ignition oil-engine has no foundation, since his first compression-ignition engine was not produced until five years after the production, on a commercial scale, of the C.I. engine of Akroyd Stuart. Also enclosed with the catalogue is a loose-leaf reprint from *The Times Review of Industry* of October 1948, which gives a concise appreciation of the relative contributions of Priestman, Akroyd Stuart, and Diesel, including details of the relevant patents.

This catalogue covers diesel engines for all applications with the exception of road vehicles and the propulsion of the larger sizes of ships. After the Editor's introduction and the foreword, there is a section explaining the working principles of the diesel engine followed by a collection of definitions of technical terms useful as a guide to terminology used in the subsequent descriptions of engines. The next section, extracted from B.S. No. 649-1949, explains the significance of rated power output. This includes a table showing the relationship between de-rating and various combinations of engine-room temperature and humidity. It might have been helpful to readers accustomed to using the metric system if these temperatures had been shown in both ° F and ° C instead of only in the former.

The following section on fuel standards is mainly extracted from B.S. No. 209–1947, and this is succeeded by another entitled "Diesel fuel terms and tests." The petroleum technologist will find in this section some statements and inferences with which he cannot entirely agree, and it is to be hoped that these will be corrected in future editions. In the paragraph dealing with flash point occurs the statement: "It (the flash point) is the lowest temperature of any particular oil at which inflammable vapour is given off." It might have been better to have clarified this by adding the words "under the specified test conditions" at the end of the sentence. Further on there is the statement "purity of the fuel is usefully indicated by the hard asphalt, ash, and water content figures." This is misleading, since hard asphalt, unlike ash and water, is not an impurity but is a natural component of the fuel. Most diesel fuels have a very low hard-asphalt content, and there is no indication that fuels containing appreciable quantities give any difficulty in combustion. It has, therefore, not been thought necessary for their amount to be limited even in the case of B.S. No. 209B.

The paragraph on viscosity explains the Redwood, Saybolt, and Engler systems, but there is no reference to kinematic viscosity, which is unfortunate, since the limits in B.S.209–1947 are expressed in centistokes. In this paragraph it is also stated that: "The Redwood figures at 70° F and 100° F are those which more closely concern engine users in temperate and sub-tropical climates. A Redwood Number higher than 250 at 70° F usually means that the fuel will have to be heated." It is usual to quote the viscosities of diesel fuels meeting B.S. 209A or B Specifications at 100° F only. The second sentence would, therefore, express the equivalent meaning more consistently if it quoted a figure of approximately 130 sec. Redwood I at 100° F, and this is a limit which would be generally agreed on by those who have used heavy fuels in practical service. A lot of questions are begged by the bold statement: "to indicate how much carbon deposit one may expect to find in an engine after consuming a given quantity of fuel is the object of the Conradson carbon residue test." Quite apart from the influence of extraneous factors such as engine type, load, and service and the type of lubricating oil used, few with experience of the subject would go further than to say that Conradson carbon has an influence on the amount of carbon deposited in the engine.

There are several errors of omission and commission in the references to ignition quality. " It (ignition quality) determines the ease of cold starting . . ." tells only half the story, for recent research has shown that the volatility of the fuel plays an equally important part in the ease of starting. " It (ignition quality) is, therefore, determined by running or starting trials in standard engines . . ." is quite incorrect, because neither of the I.P. methods nor the A.S.T.M. method use a starting trial. Considerable space is given to explaining the difference between cetane number and cetene number, but there is no indication that the use of cetene number is quite obsolete and that the cetane number scale is now the only recognized standard throughout the world. Finally, one cannot allow to pass with qualification such a tendentious statement as : " An easily ignitable fuel has a cetane number of 60 or more, whilst 30 denotes a low ignition quality fuel." The majority of high-speed engines are quite satisfied with fuels in the 50/55 range, whilst many slow-speed engines can digest fuels of 30 cetane number without any inconvenience. The explanation of the difference between gross and net calorific value would have been clearer in the statement " . . . the gross calorific value, which includes the heat energy of the water vapour occasioned by burning of the hydrogen," if it had been indicated that the heat energy referred to was latent heat.

The next section offers basic information for ascertaining the power output required of an engine from a known load for generating electricity, pumping water, or compressing air.

The catalogue proper commences with lists of the names of all manufacturers classified according to the applicational service of the engine. This is followed by the lightning index which is also divided into industrial, railway traction, and marine sections. In each section the first column lists engines in the order of increasing b.h.p., and succeeding columns give the name of the manufacturer, the r.p.m., and the page and column in which will be found a detailed description of the engine concerned. These descriptions fill the final 277 pages in which manufacturers are listed alphabetically. These pages are liberally provided with photographs both of engine units and their applications, together with general arrangement and cut-away section drawings and performance curves.

The catalogue is printed on high-quality paper which gives added tone to an excellent publication. Besides being a useful reference book for the potential buyer of compression-ignition engines, it is also a mine of information for all those specializing in the fuel and lubricating-oil requirements of such engines. For the benefit of foreign readers, the introduction and foreword, the section on de-rating an engine, and the instructions on how to use the lightning index are repeated in French, Spanish, and Portuguese. L. E. L.

BOOKS RECEIVED.

Structure of Molecules and the Chemical Bond. Y. K. Syrkin and M. E. Dyatkina. Translated and Revised by M. A. Partridge and D. O. Jordan. London : Butterworths Scientific Publications, 1950. Pp. ix + 509. 63*s*. By post 1*s*. 3*d*. extra.

This translation is based on the Russian edition published in 1946, but the text has been revised as required by the advances which have been made since that date. It is a comprehensive account of the present state of our knowledge of the ways in which atoms combine to form molecules, and deals with the contributions to the subject which have been made by both theoretical and experimental studies.

N.V. Koninklijke Nederlandsche Petroleum Maatschappij, 1890–1950. S. Gravenhage : The Company, 1950. Pp. 213.

A volume to celebrate the 60th anniversary of the Royal Dutch Petroleum Co., which was founded on July 16, 1890. In its nine chapters the book outlines the activities of the company, and there are many excellent pictorial illustrations. A map in a pocket at the back of the book shows the location of the Group's oilfields, refineries, bunkering stations, etc.

British Standards (British Standards Institution, London).

B.S. 598 : 1950. **Sampling and Examination of Bituminous Road Mixtures.** Pp. 33. 4*s.*, post free.

B.S. 18 : 1950. **Tensile Testing of Metals.** Pp. 19. 2*s.* 6*d.*, post free.

B.S. 870 : 1950. **External Micrometers.** Pp. 19. 2*s.* 6*d.*, post free.

B.S. 1127 : 1950. **Circular Screwing Dies and Hexagon Dienuts.** Pp. 7. 1*s.*, post free.

B.S. 1620 : 1950. **Dimensions of Screened Magnetos.** (G, K, and M types.) Pp. 22. 2*s.* 6*d.*, post free.

B.S. 328 : 1950. **Twist Drills and Centre Drills.** Pp. 55. 6*s.*, post free.

Machinery and Equipment—Export Facilities and Delivery Periods. Paris : Organization for European Economic Co-operation, June–July 1950. Pp. 131 + v.

Twelve countries, members of O.E.E.C., have submitted lists of delivery times. Sections 8330 and 8340 (pages 43–7) deal with specialized oil-well drilling and refining equipment, and with pumping equipment.

Twentieth Century Petroleum Statistics 1950. Dallas, Texas : DeGolyer and MacNaughton, 1950. Pp. 80 + 80 charts. $7.50.

This sixth edition of DeGolyer and MacNaughton's annual statistical reference volume follows the lines of previous editions and brings the information up to 1949. Eleven of the eighty tables and their accompanying charts are devoted to world production and reserves, the remainder covering a wide range of data concerning production, refining, and demand in the U.S.

APPLICATIONS FOR MEMBERSHIP OR TRANSFER.

SEPTEMBER 1950.

The following have applied for admission or transfer to the Institute. In accordance with the By-laws, the proposals will not be considered until the lapse of at least one month after the publication of this *Journal*, during which time any Fellow, Member, or Associate Member may communicate by letter to the Secretary, for the confidential information of the Council, any particulars he may possess respecting the qualifications or suitability of the candidate.

The object of this information is to assist the Council in grading the candidate according to the class of membership.

The names of candidates' proposers and seconders are given in parentheses.

Applications for Membership.

BARTLETT, Denis, chemist, Kuwait Oil Co. Ltd. (*R. L. Wilson ; E. Boaden.*)

BEEBE, Ralph David, lubricants supervisor, Shell-Mex & B.P. Ltd. (*H. E. Priston ; F. Lawrence.*)

BOYLE, Norman Forbes, senior shift control, Anglo-Iranian Oil Co. Ltd. (*W. B. Taylor ; E. C. Johnson.*)

CABOT, Louis Wellington, managing director, Cabot Carbon Ltd. (*J. S. Parker ; V. Biske.*)

CHATWIN, Alexander Harold, oil testing chemist, Kuwait Oil Co. Ltd. (*R. L. Wilson ; E. Boaden.*)

COLENUTT, Frederick Hugh, refinery engineer, Kuwait Oil Co. Ltd. (*R. L. Wilson ; E. Boaden.*)

COX, John Thomas, agent, The Neuchatel Asphalte Co. Ltd. (*M. J. Aldrick ; E. J. Venis.*)

DAVIES, Glyn, sales technical advisory representative, Shell Co. of Federation of Malaya Ltd. (*E. A. Crabbe ; G. M. Barrett.*)

DRIVER, Raymond Patrick, operator, National Oil Pty. Ltd. (*G. E. Mapstone ; G. Sell.*)

EDMINSTER, James Willis, technical superintendent, Cabot Carbon Ltd. (*J. S. Parker ; V. Biske.*)

ELPHICK, Oscar James, chemist, Messrs. Edwin Cooper & Co. Ltd. (*J. Romney ; W. R. Steet.*)

HOGAN, William Joseph, research chemist, National Oil Pty. Ltd. (*G. E. Mapstone ; G. Sell.*)

JACKSON, Peter Buchanan, manager, Messrs. Martin Burn Ltd. (*A. L. Read ; V. B. Wright.*)

LEAHY, Patrick Joseph, chemist, Kuwait Oil Co. Ltd. (*R. L. Wilson ; E. Boaden.*)

LEWIS, Geoffrey Kenneth Kirby, sales assistant, Anglo-American Oil Co. Ltd. (*T. C. R. Baker ; R. D. Streeton.*)

MALBOS, Pierre J., laboratory chief, Central de Shell Francaise. (*W. Pohl ; C. W. G. Martin.*)

MILNE, Robert, junior petroleum engineer, Iraq Petroleum Co. Ltd.

NORMAN, Jack, assistant to deputy general manager, Iraq Petroleum Co. Ltd. (*O. H. Griffiths ; D. M. Bremner.*)

PATTIE, James Watson, (Retired). (*G. H. Smith ; W. B. Peutherer.*)

PETERSEN, Axel Thorvald, managing director, Messrs. C. C. Wakefield & Co. Ltd. (*G. H. Thornley ; W. F. List.*)

REECE, Henry Water Walton, chemist, Kuwait Oil Co. Ltd. (*R. L. Wilson ; E. Boaden.*)

RUSSELL, Thomas Wood, assistant engineer, Iraq Petroleum Co. Ltd. (*O. H. Griffiths ; D. B. Bremner.*)

RYLAND, Frederick Claude, deputy general manager, Iraq Petroleum Co. Ltd. (*O. H. Griffiths ; D. M. Bremner.*)

VRBA, Paul, student of chemical engineering, University of Birmingham. (*F. H. Garner ; F. Morton.*)

WADDINGHAM, Charles William, assistant installation manager, "Shell" Refining & Marketing Co. Ltd. (*J. G. Hancock ; L. F. Elsby.*)

WALLEN, John Isidore Anthony, draughtsman, Uni-Gun Lubricating Equipment Ltd. (*P. Kerr ; G. Sell.*)

WILSON-IRVING, George Arthur, assistant mechanical engineer, Kuwait Oil Co. Ltd. (*H. C. Lack ; R. L. Wilson.*)

WOODFINE, Robert John, sales assistant, Anglo-American Oil Co. Ltd. (*R. D. Streeton ; T. C. R. Baker.*)

YULE, Robert, chemist, Petrochemicals Ltd. (*E. J. Dunstan ; W. E. Huggett.*)

Transfer.

HAMBLIN, Robert Jeremy John, chemical engineer, Trinidad Leaseholds Ltd. (*B. G. Banks; P. H. B. Fraser.*)

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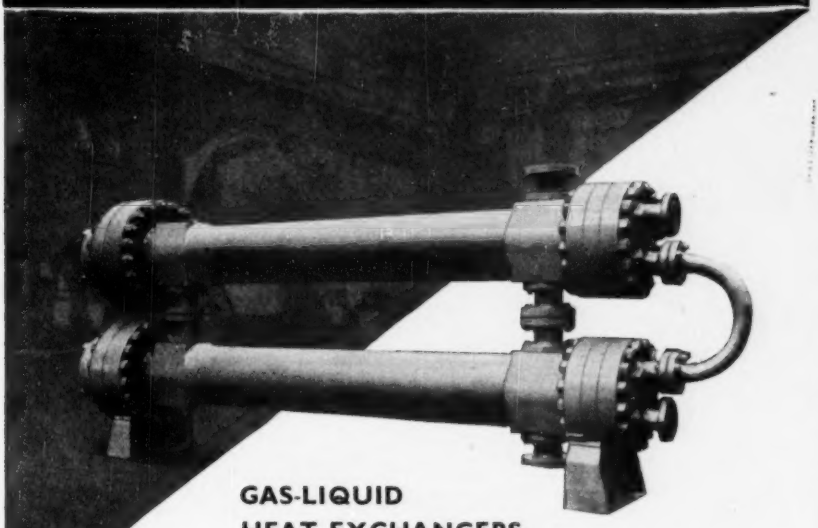

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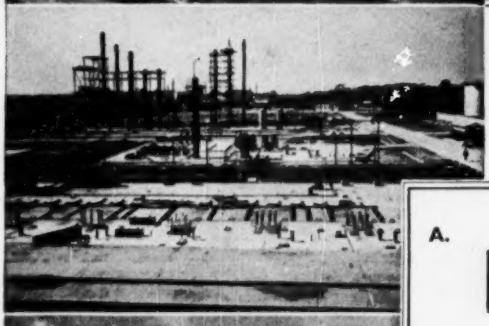

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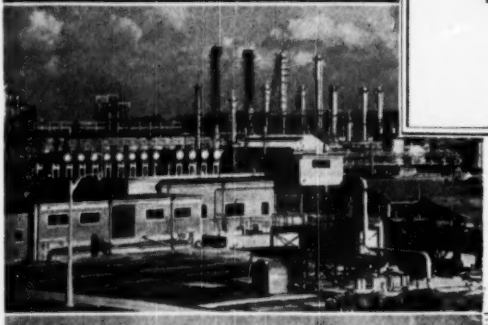

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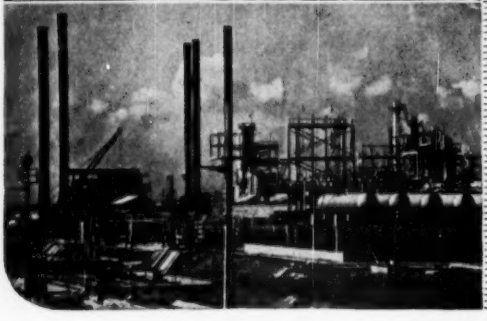

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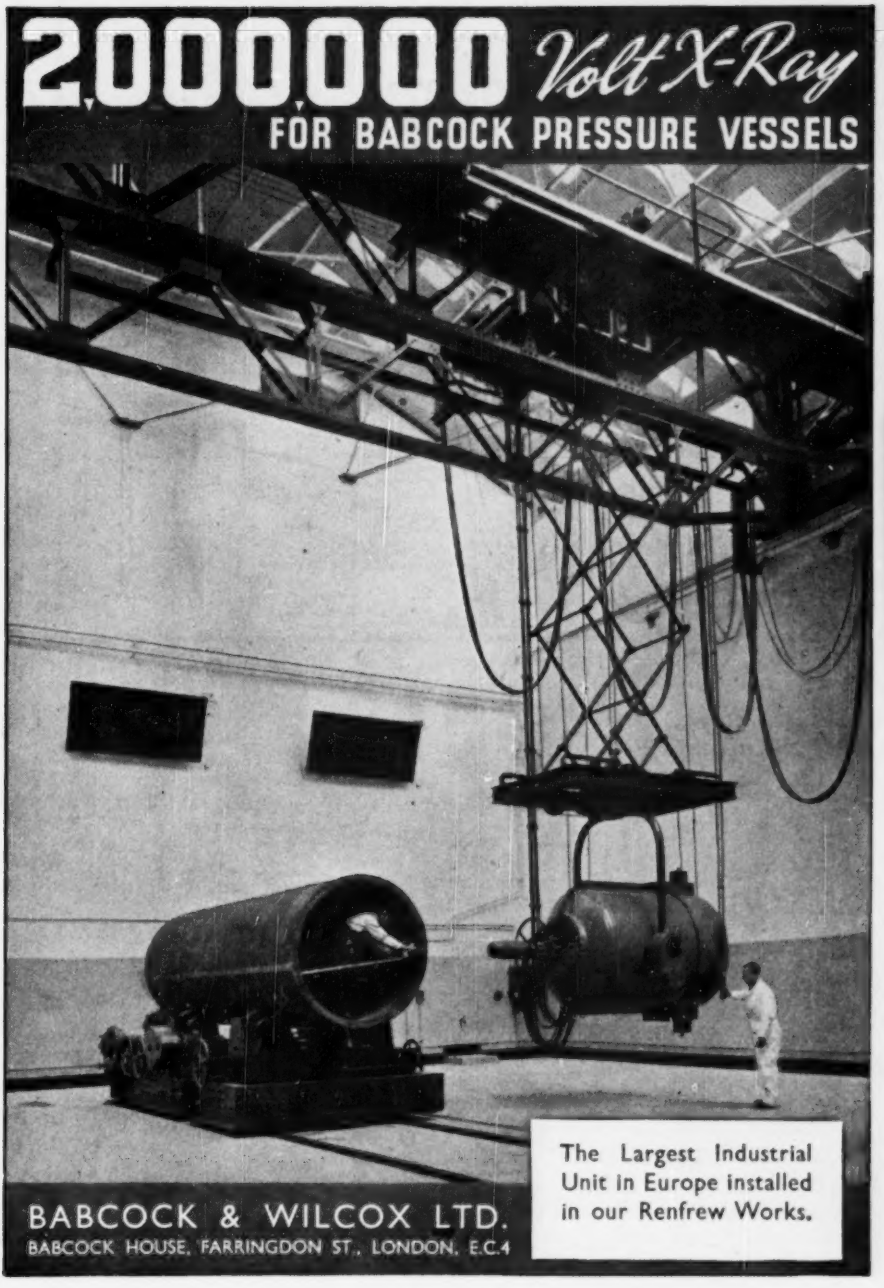
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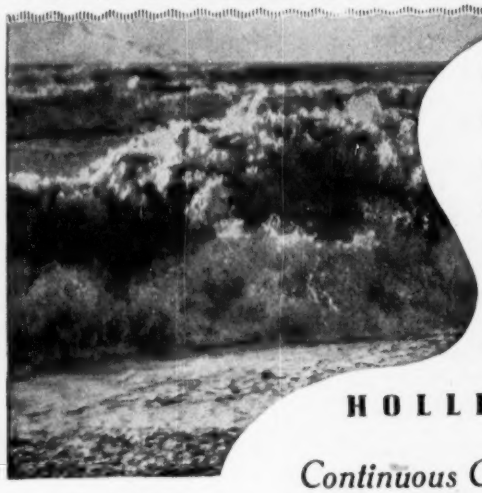

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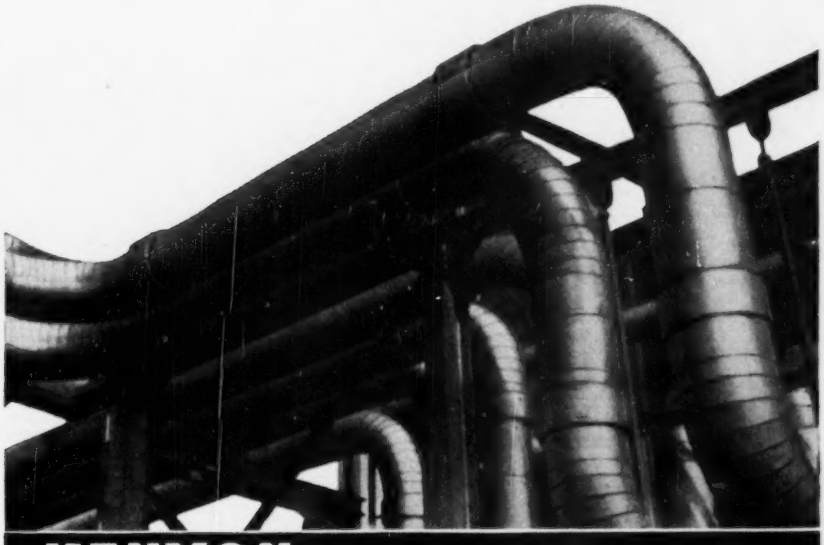

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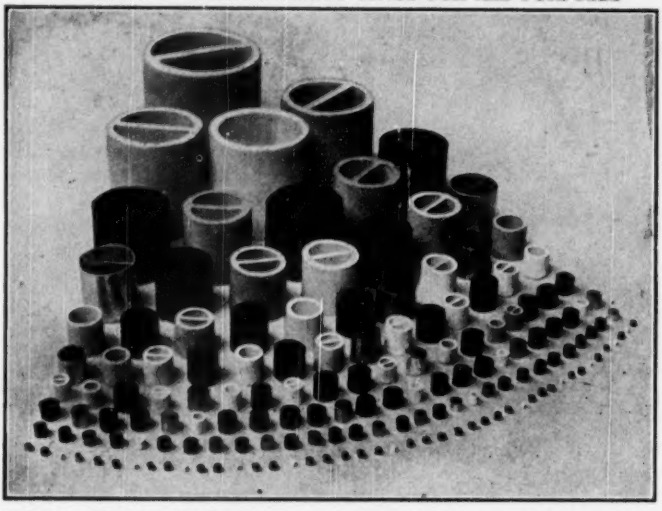

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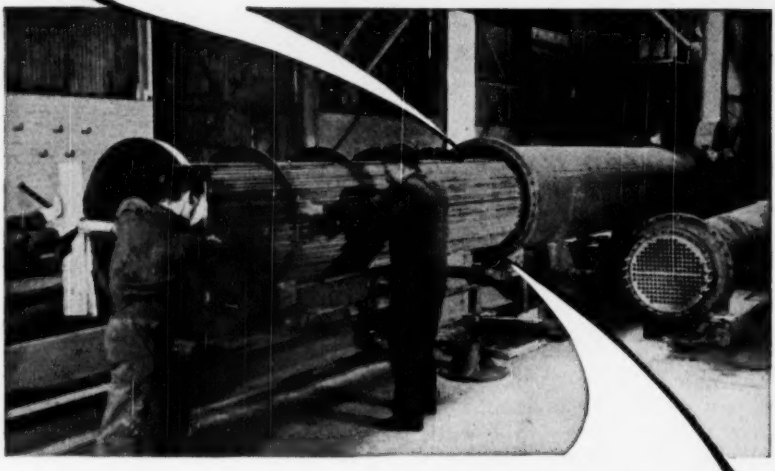

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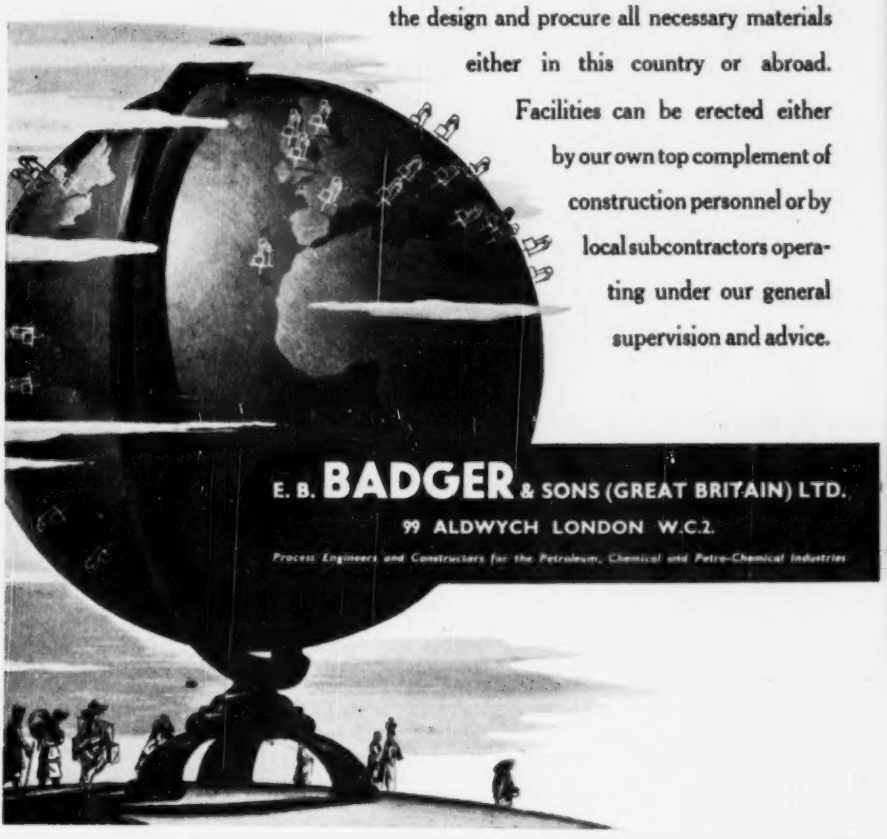
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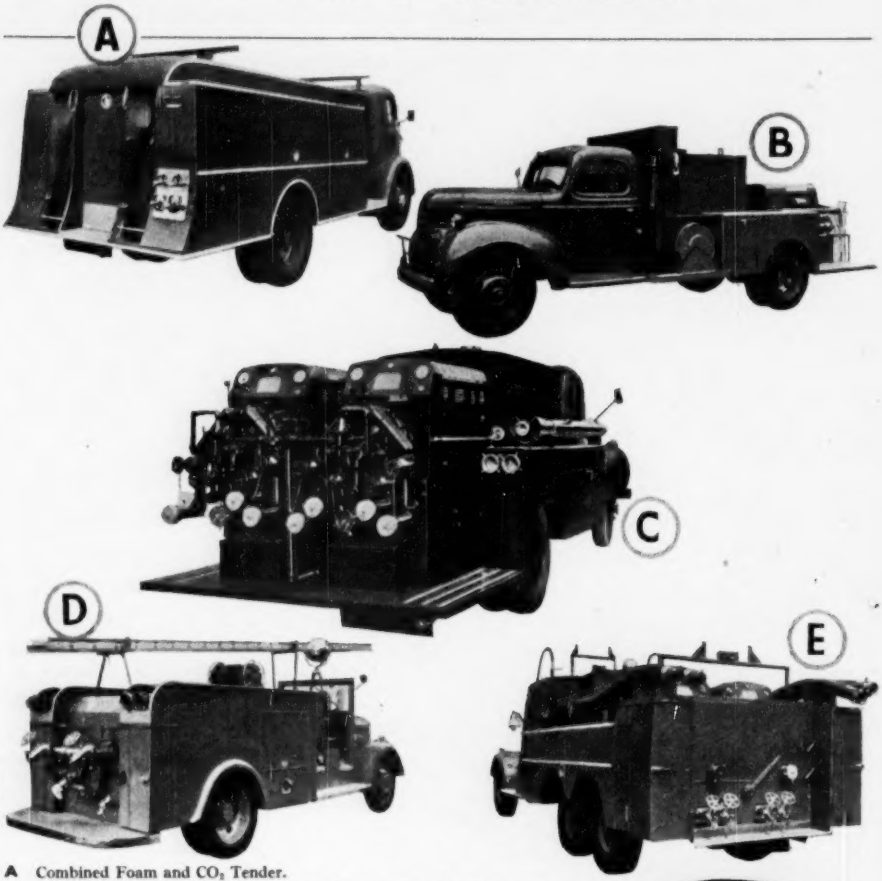

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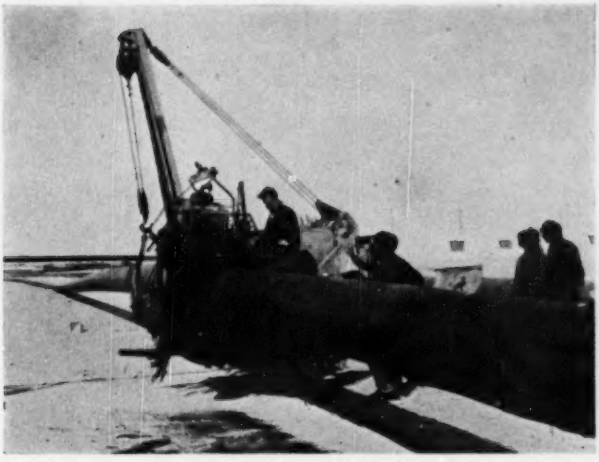

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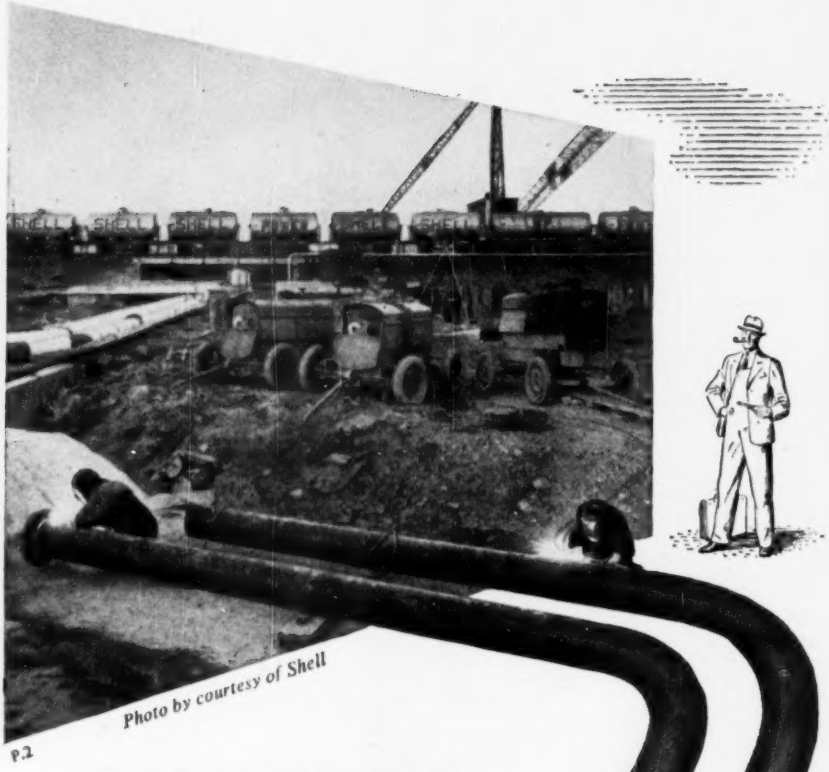

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P.2

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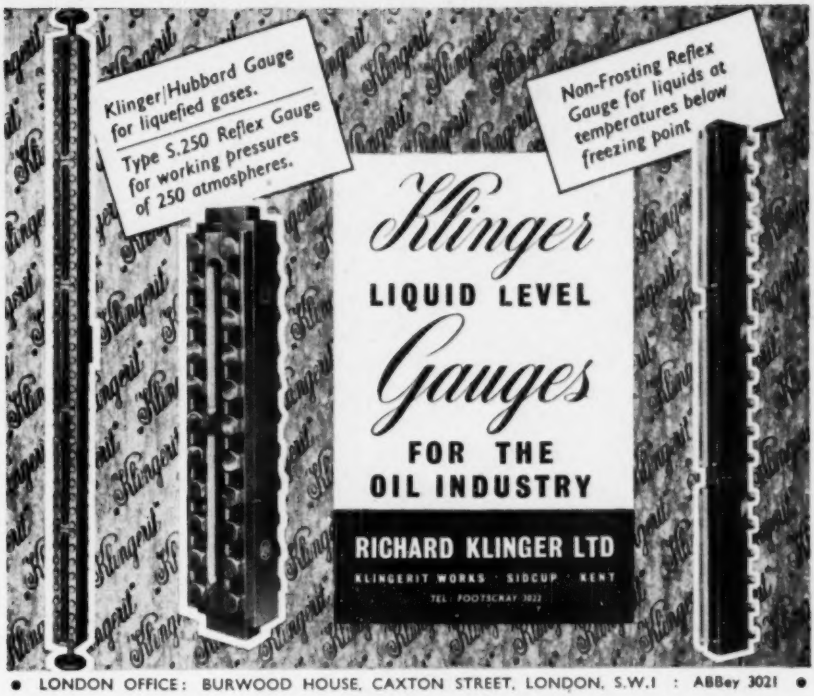
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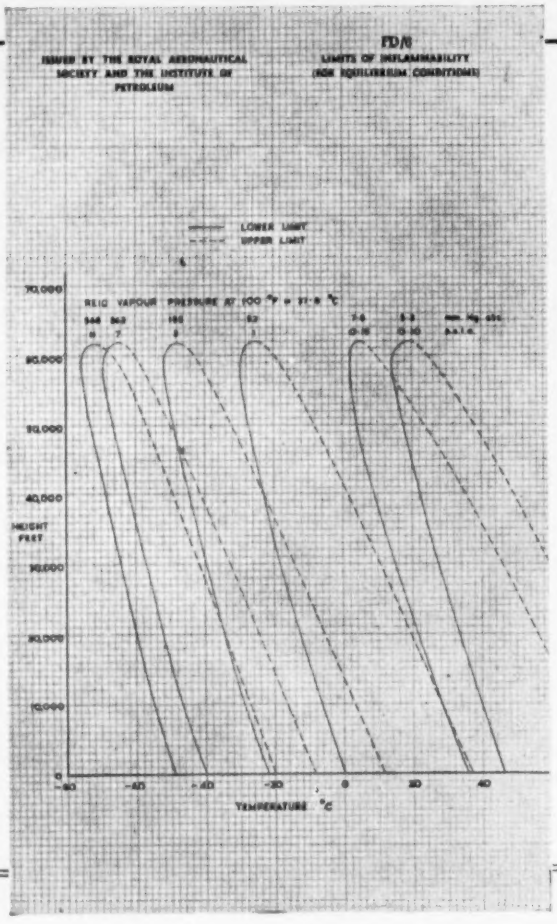

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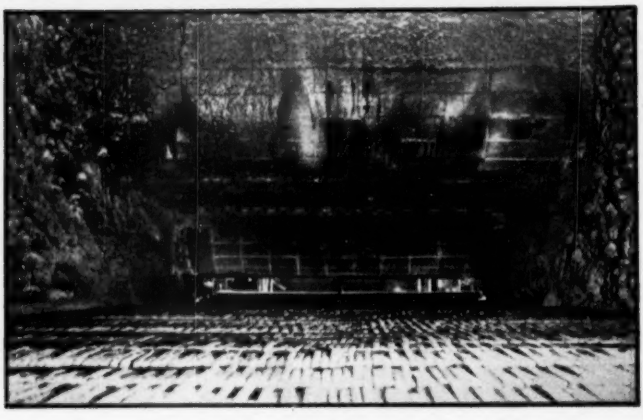

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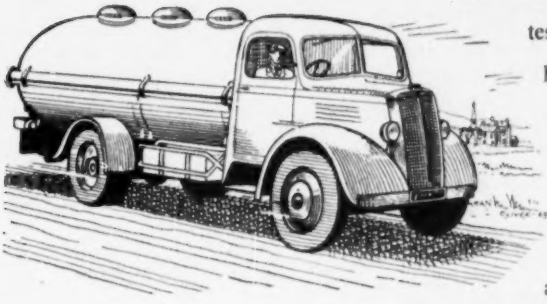

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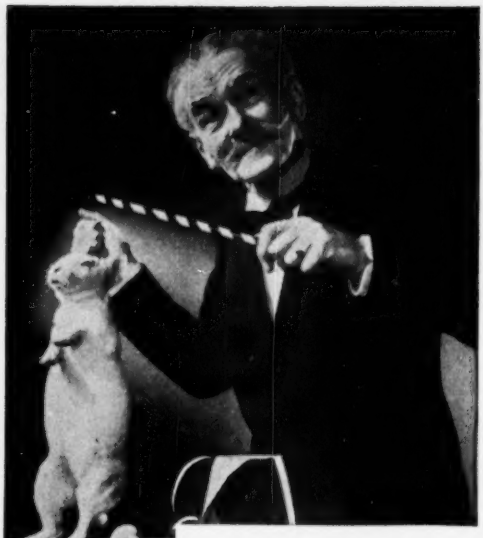

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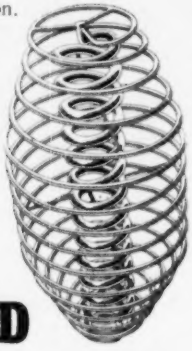

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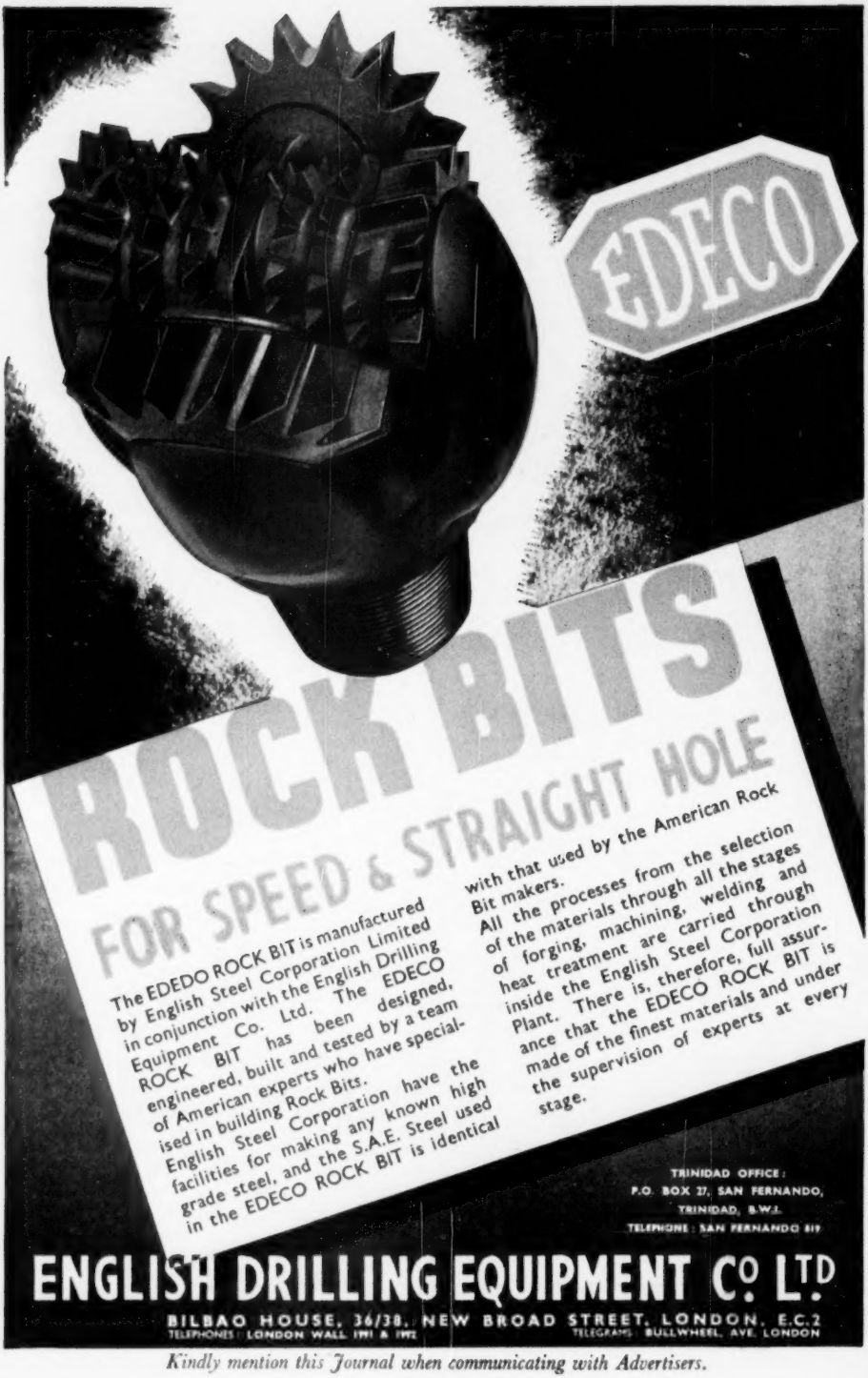
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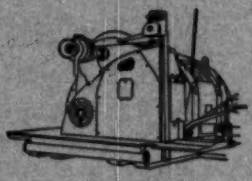

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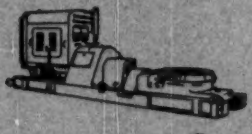

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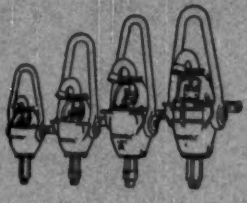

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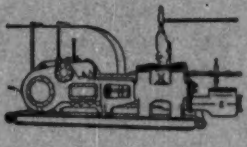

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